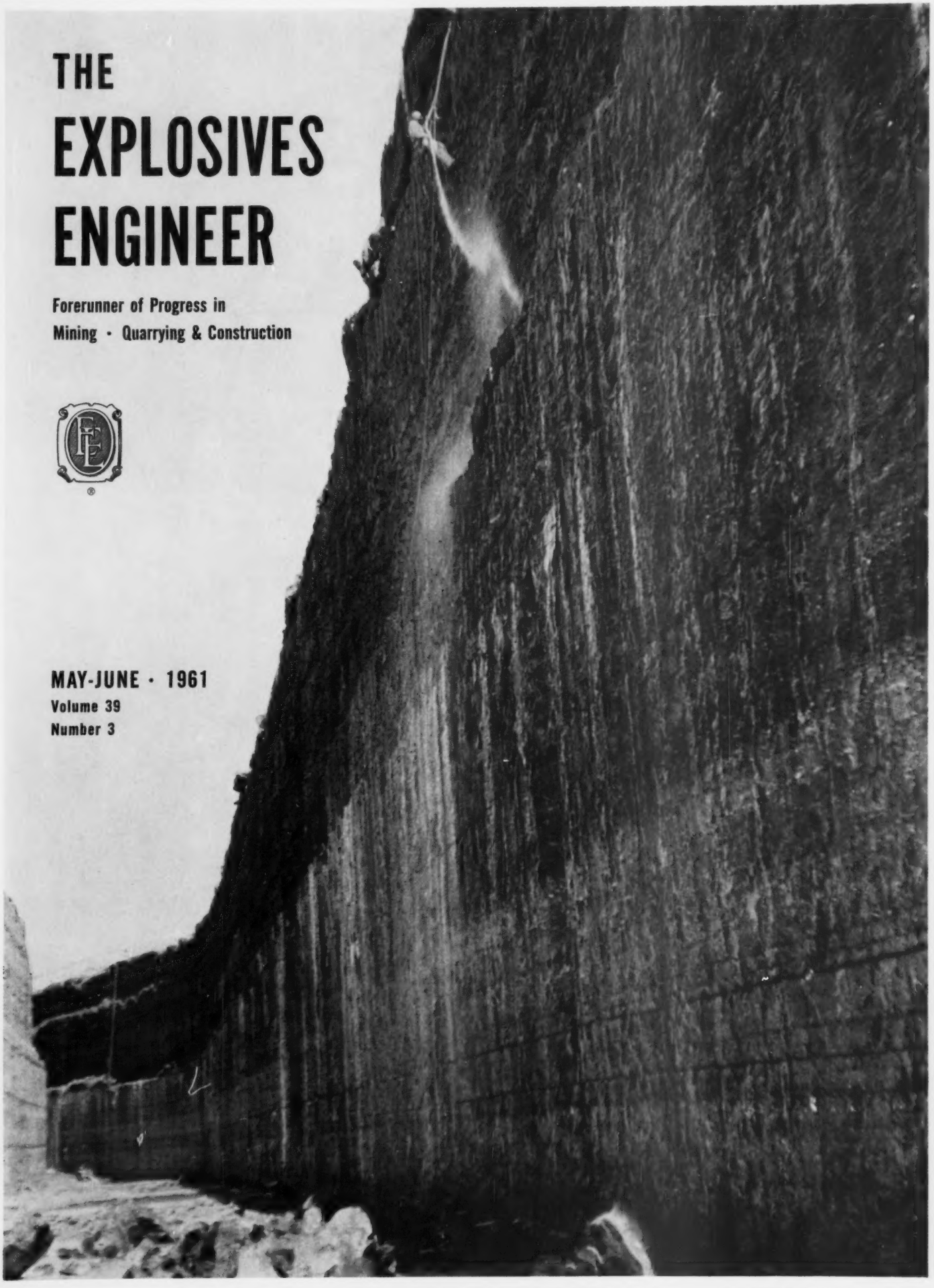
THE EXPLOSIVES ENGINEER

Forerunner of Progress in
Mining · Quarrying & Construction



MAY-JUNE · 1961
Volume 39
Number 3

Hooking up the holes proceeds without danger of premature detonation from stray electric currents.

Delay connectors are attached to Primacord downlines; LEDC trunklines are cut and crimped into these connectors.

The dual connections are taped securely together and the ends of the Primacord downlines are tied.

ENSIGN-BICKFORD LEDC helps solve blasting noise problems at General Crushed Stone Quarry

The Glen Mills Quarry of the General Crushed Stone Company at Glen Mills, Pa., is located in the heart of a residential area. *And its neighbors don't like noise!*

The quarry produces aggregate from hard granite gneiss, very blocky and seamy. High explosives are used with Primacord downlines for in-hole initiation. These downlines are hooked into a surface system of LEDC trunklines and Delay Connectors.

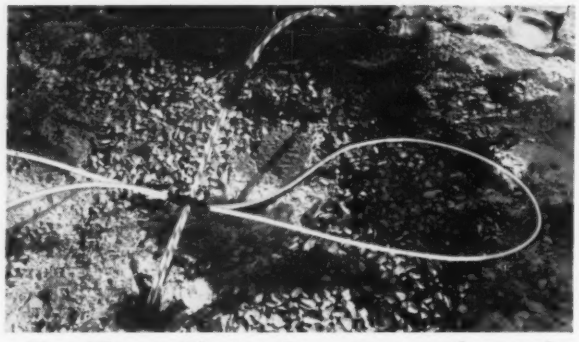
Danger of Prematures Minimized

Blasts are set off at a specified time each day. This means that loaded holes may stand for several hours before blast time. To minimize danger from stray electric currents, the electric blasting caps are never attached until the last minute.

The use of trunklines of Ensign-Bickford Low Energy Detonating Cord has practically eliminated the noise problem—and without danger of premature shots from stray currents.

This blast was set off on December 6, 1960. It consisted of eight 7-in., 50-ft. holes at 15-ft. intervals in a line 20 feet back of the base of a 46-ft. face. Loading was under the direction of Harry Kemery, Superintendent, Morton McGuirk, General Quarry Foreman, and the powder company representative. High explosives were used with two primers in each hole, initiated by Plastic Wire Countered Primacord downlines.

A continuous line of LEDC was laid from Hole No. 8 to Hole No. 1 and back again, forming two trunklines. Delay Connectors were attached to each downline, and the trunklines were cut and crimped into the Connectors, which were then taped securely together.



Two Electric Blasting Caps were taped onto the Primacord downlines at No. 1 Hole, which fired instantaneously. Succeeding holes were progressively delayed 15 milliseconds.

Noise was no problem! . . . just the normal thud of explosives breaking rock.

Ensign-Bickford LEDC is a Low Energy Detonating Cord with two grains PETN per foot, encased in a lead tube and protected by a plastic jacket. It detonates throughout its entire length at nearly four miles per second, but detonation noise is *low*. 150 feet of LEDC makes no more noise than a single blasting cap!

LEDC will not directly initiate Primacord or other cap-sensitive explosives but must be used with delay connectors. LEDC is made only by Ensign-Bickford. Both LEDC and delay connectors are available through all explosives manufacturers.

If you have blasting noise problems, LEDC may be the answer. Write for free bulletin; also a free copy of the new Primacord catalog and manual is available through your explosives manufacturer—or write giving your company name.

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EB

THE EXPLOSIVES ENGINEER

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Forerunner of Progress in Mining, Quarrying, Construction

It is seldom that we devote an entire issue of THE EXPLOSIVES ENGINEER to the activities of one company or to one single development in the art of using explosives.

However, the recently developed technique of presplit blasting has had such outstanding success on the work sections of the Niagara Power Project where it was used that we feel justified in reporting in much more detail than is our editorial custom.

The Niagara Power Project basically consists of an intake section, two parallel conduits about 4 miles long, an open canal 4,000 ft. long, a main generating plant, and a pump-generating plant. The foregoing generalization of the project must be considered an oversimplified description when you look into some of the details of the job. For example, consider the one item of excavation. In six work sections a total of approximately 38,846,000 cu. yd. of material had to be removed and the majority of this material was rock which required blasting. Also, there were several million sq. ft. of rock face that had to be prepared to within a tolerance of 6 in. This takes skillful blasting.

At the start of the project several different methods of establishing the break line were tried by the various contractors. However, none of these methods gave really clean walls; and it was not until D. K. Holmes, drilling and blasting superintendent for Merritt-Chapman & Scott Corp., developed presplitting that superior results were obtained.

Further experiments with presplitting show a great variety of possible applications. This method can be applied to railroad and highway cuts, tunnels and other underground excavations, spillways, flumes, and other places requiring clean rock faces. The transmission of vibrations can be greatly lessened when presplitting is used at building excavations, at quarries, and other blasting operations.

EDITORIAL STAFF: JAMES J. O'NEILL, *Editor;* THOMAS E. MILLER, *Associate Editor;* GERTRUDE A. DONNELLY, *Associate Editor;* EDWARD L. GRANT, *Art Editor;* HOWARD B. DICKSON, *Production Manager;* A. J. ACKERMAN, *Advertising Manager;* MONTGOMERY R. BUDD, *Director.*

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By ROLF S. PAINE, D. K. HOLMES, and HARRY E. CLARK

Views and opinions expressed by the authors of articles in this publication are their own, and they do not necessarily represent those of the publisher.

The article "Presplit Blasting at the Niagara Power Project" is the result of the combined efforts and varied talents of three men, a mining engineer, a geologist, and a mathematician, who not only collaborated in the engineering research and the many experiments required but also in the practical application of their findings. A brief look into the technical background and field experience of the authors reveals their qualifications.

Rolf S. Paine received his degree in geology from Princeton, where he majored in mineralogy. His practical field experience consists of stints in tungsten mining in the Mojave Desert and gold dredging in British Guiana. He also spent much time in the mining and construction field of Central and South America and the West Indies and established a mining supply house in Venezuela where he specialized in contract drilling and blasting. Mr. Paine is currently a sales-service representative for the Explosives Department of Hercules Powder Company.

D. K. Holmes received his bachelor's degree in mining engineering from the University of Arizona after transferring from Dartmouth. After working in the metal mines in various parts of the United States he became an Explosives sales representative for Hercules Powder Company. He then entered the heavy-construction field and was drilling and blasting superintendent for Merritt-Chapman & Scott Corp., on the Niagara project. Mr. Holmes is currently assistant project manager for Merritt-Chapman & Scott on its contract for Cougar Dam.

Harry E. Clark, who is in the Applied Mathematics Division of Hercules Powder Company's Research Department, received his master's degree in mathematics from the University of Delaware after obtaining a bachelor's degree in history from the same university. Mr. Clark's specialty is the solving of problems in the chemical industry by the application of mathematical analysis and electronic computer techniques.

It is with a great deal of pleasure that we present their comprehensive report, "Presplit Blasting at the Niagara Power Project," which starts on page 71.

* * *

We are indebted to *The Texaco Star*, a publication of Texaco, Inc., for the color photograph shown on our cover.

Meet Denis Plan
the Hercules Technical Man
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of Short-Period Delays
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MOST RESPECTED NAME IN THE INDUSTRY

Ronald Russel McNaughton

PRESIDENT OF THE A.I.M.E.

A Biography

THE first Canadian ever elected president of the American Institute of Mining, Metallurgical, and Petroleum Engineers is Ronald Russel McNaughton, manager of the Metallurgical Division of The Consolidated Mining and Smelting Company of Canada, Limited. Furthermore, this Canadian comes of such staunch Empire stock that his ancestors were among the United Empire Loyalists who left the United States at the time of the Revolution to settle in Glengarry County, Ontario. That was so long ago, however, that most U. S. citizens have forgiven them for their defection.

His father, Peter McNaughton, and his mother, Marie H. McIntosh, both descendants of good Scots, left eastern Canada, and became pioneers of the city of Vancouver in its early days. Both parents were active in the early civic life of Vancouver. Peter McNaughton was a Mason and became Grand Master of his lodge; Marie was elected the first woman school trustee of the city, possibly to improve the education her sons and daughter were receiving. Ronald Russel attended the Lord Roberts Public School, the King George High School, and the Victoria High School. From there he entered the University of British Columbia, studying arts for a year, then went off to McGill University, from which he graduated with honors in 1923 with a degree of Bachelor of Science in Metallurgical Engineering.

The new president of the A.I.M.E. played the violin in several school orchestras and chamber groups, and participated particularly in water sports, for his Vancouver home was but a step from the ocean.

At the age of nine he delivered and sold the *Saturday Evening Post*, and as a boy of twelve he worked the summer as a handy man in the stock room of the Cadillac dealer of Vancouver because a group of barnstorming race drivers, including Barney Oldfield, stabled their cars there. Between high school and college he held many jobs ranging from motorcycle mechanic to fruit car loader foreman and laborer at the Hollinger Mine.

Ron McNaughton joined Cominco after graduating from McGill, where they set him to testing tanks in the Betts process electrolytic lead refinery. After that he spent two years in the Assay Office.

He was one of three university graduates put on the lead smelter staff as assistant foremen, where he learned about "muscular metallurgy" and developed a fine appreciation for the men who had learned their lessons the hard way. When pulverized coal was substituted for oil, the college boys were told to make it work. Ron says he still has coal ingrained in his hide from that job.

His present post as manager of the Metallurgical Division embraces the reduction and refining of metals including lead, zinc, silver, cadmium, bismuth, gold, indium, and antimonial lead. Cominco, employing 7,000 people, is one of the world's largest producers of these metals as well as chemical fertilizers.

Ron McNaughton has been active in his profession as a member of the Mining and Metallurgical Society of America; the Canadian Institute of Mining and Metallurgy, which awarded him the Selwyn G. Blaylock Medal this year; chairman of the Extractive Metallurgy Division, and of the Metals Branch of the A.I.M.E. Last year he was a director and member of the executive committee of the A.I.M.E.

Mr. McNaughton and Mrs. McNaughton, the former Dorothy Millen of Montreal, live at 12 Ritchie Avenue, Trail, British Columbia. They have two sons, John Richard and Peter Ronald, both married, and one granddaughter.

RONALD RUSSEL McNAUGHTON

Editorial

Can Government Research Help Coal?

Recently we have been noting signs of increasing activity in the Office of Coal Research of the United States Department of the Interior. The initial meeting of the Advisory Committee will be held June 6, according to a recent press release. The announcement of this meeting stated as a *raison d'etre* that "the reduced consumption of coal in the United States and a parallel reduction in the number of coal workers have brought acute distress in many parts of the country." While not a new thought to anyone even vaguely familiar with economic conditions in the United States, it is, nevertheless, one with which few can quarrel. The announcement, however, goes on bravely to say that "the Office of Coal Research can and will make a major contribution to the solution of many of these pressing problems." If so, we would be wholeheartedly in favor of backing this committee to the limit.

Something of the philosophy and the thinking of the Department of the Interior in regard to this committee and the task facing it was set forth recently by a representative of the department. Speaking at the 1961 Coal Show, John M. Kelly, assistant secretary of the Interior for Mineral Resources, discussed the newly organized Office of Coal Research, and suggested some of the problems which it should tackle. "The time has now come to pool our research energies to attack old problems, to find new and better uses for coal." Some of these problems listed were: the use of coal as an industrial commodity, the gasification of coal, the creation from coal of a liquid fuel, and efficient, inexpensive new methods to transport coal. Truly a formidable list, and if the coal research committee could come up with a far-reaching solution to even one of them, it would do much to alleviate the economic distress which the industry now suffers.

It is perhaps not surprising that the Department of the Interior should think of pooling research energies to arrive at a solution for coal. We in America are accustomed to pooling resources. We pool funds to create a larger economic unit, the corporation, than we could achieve by using the resources of one individual; we pool the energies of citizens to accomplish a big community project; we pool men and money to meet disaster when it strikes at some part of our country. But most directors of scientific research would probably agree that except for checking out of possible solutions, the pooling of scientific brains is of doubtful benefit. Two scientists working together probably are no more likely to come up with a discovery than are the same two scientists working separately.

We think that what *Barron's* weekly had to say recently about the Office of Saline Water, another research project of the Interior Department, may prove to be true also of the Office of Coal Research. That weekly said of the OSW, established in 1952, "Unfortunately, there is scant hope that a federal agency will achieve any such grandiose goal" as the desalting of the sea. "To date, OSW's only concrete accomplishment has been subsidizing research and the construction of pilot and demonstration plants. . . . Admittedly, some of its grants yet may open new frontiers in technology. Any such advances, however, will owe more to the initiative of the private companies involved than to any master planning."

Looking at the list of scientific advances which have come out of government research laboratories, it would seem that the coal companies would be well advised not to forsake their faith in the scientific advances that have stemmed from private companies and their laboratories.

Blasting Cap Accidents Decreasing

One pleasant trend which will please all those who make use of blasting caps is the decrease in blasting cap accidents to children, declining now for the fourth successive year. The present year, if it should continue as favorably as it has gone thus far, would bring a new low in accidents to children from this cause as measured by the statistics compiled by the Institute of Makers of Explosives.

This favorable trend can be attributed at least in part to the efforts of the schools, Boy Scouts, newspapers, TV, and radio to carry the Institute's warning to children, and an ever-increasing awareness of the danger on the part of the users of caps. The regular users of caps, who by and large make up the majority of the readers of THE EXPLOSIVES ENGINEER, have kept their caps away from children for many years.

With the number of accidents decreasing to new lows, all of us are likely to fall into the error of thinking that the problem has been solved, and that vigilance in this regard can be relaxed. A moment's thought, however, will indicate that the problem is always with us. Always younger children are coming along who, unless warned, are unaware of the danger of playing with caps, and of the power of the explosive contained in the tiny metallic shells. That is why the Institute's program has continued vigorously for over a quarter century.

PRESPLIT BLASTING

At the Niagara Power Project

Overbreak was controlled, safety increased, and economies in manpower and concreting resulted with the introduction of presplitting

PRESPLIT BLASTING AT THE NIAGARA POWER PROJECT

ROLF S. PAINE,* D. K. HOLMES,† AND HARRY E. CLARK‡

MEN, machines, and ingenuity are now in the third year of building the $720-million Niagara Power Project. This is one of the Western World's most ambitious hydroelectric developments and, when completed in 1962, will be capable of producing 2,190,000 kw. of electrical energy. This additional power will bolster that already available in the Buffalo-Rochester-Syracuse-Utica area and will open up this region to new industries as well as provide for expansion of those industries already established.

*Hercules Powder Company
New York City, New York
†Merritt-Chapman & Scott Corp.
New York City, New York
‡Hercules Powder Company
Wilmington, Delaware

An almost perpetual source of water is available to operate the huge turbines being installed at the principal generating plant under construction by Merritt-Chapman & Scott Corp.; the pump turbines are being installed by Tuscarora Contractors. The drainage of a large section of the northern United States, an area extending from New York State to Minnesota, plus a section of southern Ontario, flows into the Great Lakes. This area comprises a watershed of 263,440 sq. mi. It is the flow of water from Lakes Superior, Michigan, Huron, and Erie via the Niagara River that makes the Niagara Power Project possible.

Basically, the project consists of an intake section, two parallel conduits about 4 mi. long, an open canal 4,000 ft. long, a main generating plant, and a pump-generating plant. The intake structures lie just to the east of the confluence of the two channels, the Chippewa and the Tonawanda, on the north bank of the Niagara River.

Records indicate that over a period of 94 years the average mean flow of water in the Niagara River has been at the rate of 202,500 c.f.s. This large volume of water could be diverted, almost in its entirety, from the Canadian falls and the American falls through the intake of the Niagara Power Project and the existing Sir Adam Beck intakes. However, this will not be permitted because of an international agreement between Canada and the United States, which limits the amount of water that can be diverted. During daylight hours, when the touring public is usually present to view the beauty of one of nature's wonders—the cataracts of the Niagara—at least 100,000 c.f.s. must flow over the falls. At night, when the scenic beauty of the falls is not of such great consideration, this flow can be reduced to

PARALLEL CONDUITS: This aerial photo gives an excellent view of the twin parallel conduits. Walls prepared by the presplit method of blasting can be seen in the area from the curve to the flume.

50,000 c.f.s. The remainder of the flow available during the night is shared between the United States and Canada. Also, they share in the permitted amount that can be withdrawn during daylight hours.

The American share of the water that can be withdrawn during the night is calculated to be in excess of the amount required for producing the power demand during this period; therefore, the Tuscarora pump-generating plant, by reversing its process from generating to pumping, can place a part of this water in the Tuscarora Reservoir so that peak power can be maintained during daylight hours when the pumps are reversed again to turbines and the flow of water from the reservoir combines with that coming through the conduits and into the canal leading to the Robert Moses power plant.

The twin conduits, which measure 46 ft. wide by 66 ft. high to the crown of the arch, can handle 83,000 cu. ft. of water per second under a velocity of 14 ft. per second.

SCOPE OF PROJECT

The Niagara Power Project is comprised of several major work sections. Listing the contract price and the amount of excavation in the various sections will give an idea of the immensity of the undertaking.

Work Section No. 1 – Contract N-5 – Merritt-Chapman & Scott Corp.

Excavation, unclassified, for conduits and intake structure	4,905,300 cu. yd.
Excavation, wet, unclassified, for river channelization	2,500,000 cu. yd.
Total excavation	7,405,300 cu. yd.
Amount of contract	$65,962,256

Work Section No. 2 – Contract N-6 – Edward Balf Co., Savin Brothers, D. W. Winkleman

Excavation, unclassified	5,085,000 cu. yd.
Amount of contract	$37,366,805

Work Section No. 3 – Contract N-7 – Gull Contracting, L. G. Defelice & Son

Excavation, unclassified, for conduits	4,185,200 cu. yd.
Excavation, unclassified, for canal section	389,000 cu. yd.
Total excavation	4,574,200 cu. yd.
Amount of contract	$29,861,840

Work Section No. 4 – Contract N-8 – Channel Constructors (Peter Kiewit Sons Co., Perini Corp., Morrison-Knudsen Co., and Walsh Construction Co.)

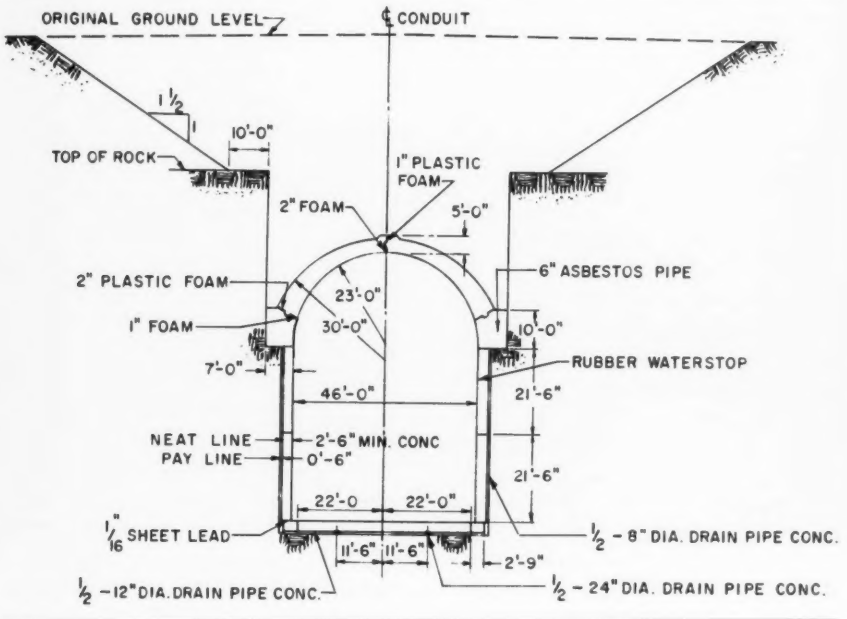
Excavation, unclassified	9,589,400 cu. yd.
Amount of contract	$31,855,000

Work Section No. 5 – Contract N-3 – Merritt-Chapman & Scott Corp.

Excavation, unclassified, for plant structure	7,000,000 cu. yd.
Excavation, unclassified, for forebay and miscellaneous	2,617,100 cu. yd.
Total excavation	9,617,100 cu. yd.
Amount of contract	$98,288,498

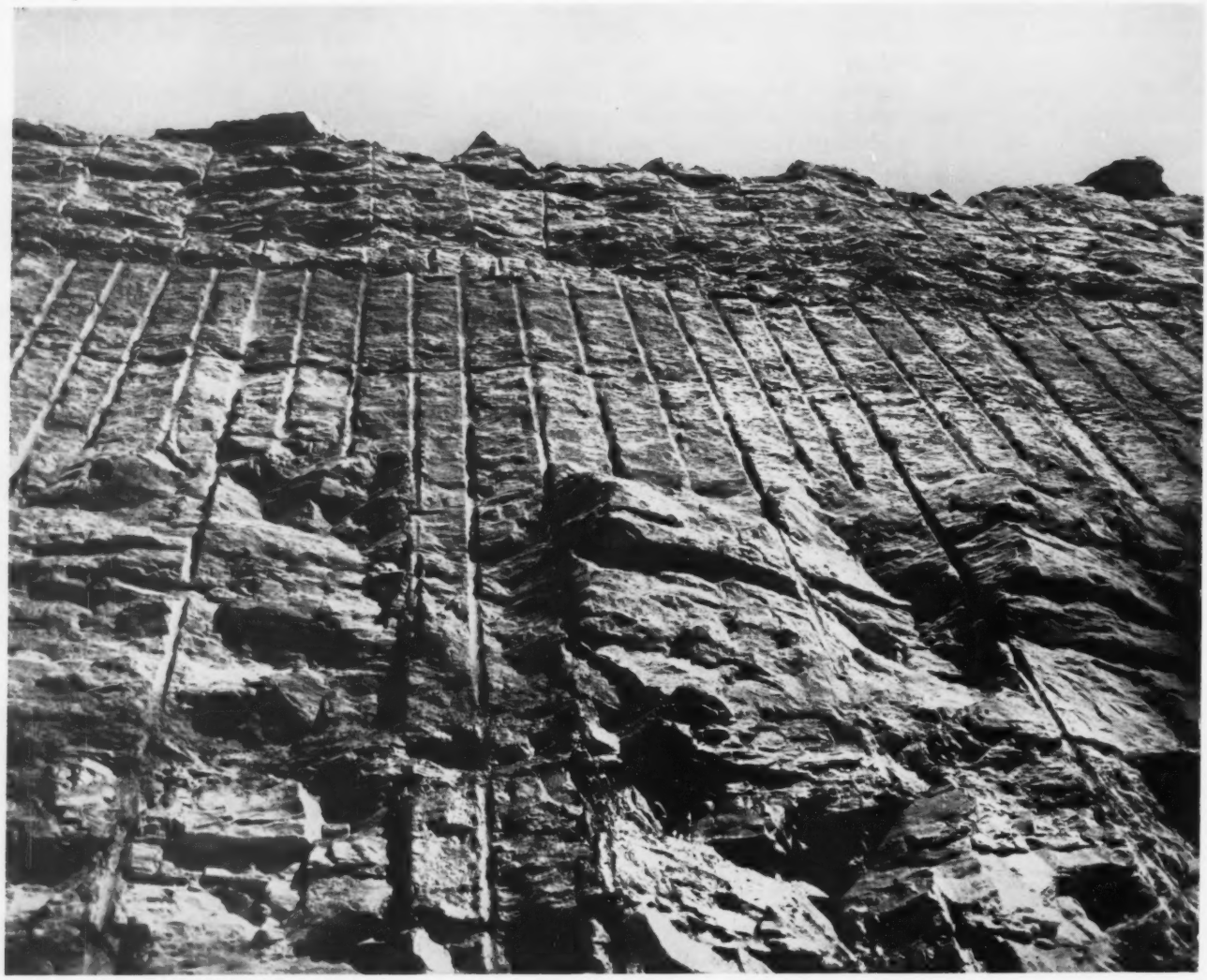
Work Section No. 6 – Contract N-10 – Tuscarora Contractors (Arundel Corp., L. E. Dixon Co., and Hunkin-Conkey Construction Co.)

Excavation, unclassified	2,575,000 cu. yd.
Amount of contract	$39,834,292



CROSS SECTION: The twin conduits, with finished dimensions of 46 ft. wide by 66 ft. high, will be able to handle a flow of 83,000 cu. ft. of water per second.

DEEP SECTION: Some vertical cuts averaged 110 ft. in depth and had to be kept within the "A" and "B" lines. In this area of the cut in Work Section 3, presplitting was done from haunch to invert only.



SLASH AND TOUCHED-UP HOLES: The upper and center sections of the wall show the results of using slash holes on 4-ft. centers, while the bottom illustrates touched-up holes, also on 4-ft. centers.

When one considers that the majority of this listed 38,846,000 cu. yd. of excavation was in rock, and that several million sq. ft. of rock face had to be prepared within a tolerance of 6 in., it is easy to see that quite a problem was presented to the various contractors to keep from overbreaking beyond the pay line, or "B" line, as it was called, with conventional methods of drilling and blasting.

Vertical cuts that averaged 110 ft. in depth had to be kept within the "A" and "B" lines. A total of 5,104,000 sq. ft. of side walls, on the conduit sections alone, had to be prepared within this tolerance. If the walls were too tight and rock extended out past the "A" line—even if only 2 in.—it had to be removed. This had to be done with "slash holes" or with paving breakers. If the rock was overbroken past the "B" line, the contractor had to pay for the extra concrete.

Geology

The bedrock geology of the Niagara Falls, New York, area is comparatively simple and consists of nearly horizontal layers of sedimentary rocks. The upper part is called the Lockport group. The first member of this group is the Guelph dolomite, which is a light gray unfossiliferous crystalline dolomite. In general, it has tight bedding planes, with occasional open joints. In columnar sections downwards is the Gasport, a light gray fossiliferous crystalline limestone with tight bedding planes and stylolites, which are small, short, transverse columnar structures; the De Ceu, a dark gray unfossiliferous cross-bedded crystalline dolomite with tight bedding planes and some stylolites; the Rochester shale, a relatively massive black shale stratified, in its upper part, with very thin bands of coquina limestone; and then sandstones and shales, until at the bottom of the gorge Queenstown shale is encountered.

Our principal interest lies in the Guelph, Gasport, and De Ceu formations, because most of the excavation was in these rocks. There is also some interest in the Rochester shale.

The open joints of the Guelph, or caprock section, made blasting to a clean break line quite difficult. Also,

this section of the Lockport group contained stresses which had not been released completely when the continental glaciers melted and rebound or uplift occurred. Blasting this stressed section opened incipient fractures in the rock and caused an inward movement of the formation. Other sections of the Lockport group also appeared to contain these stresses, but were not as difficult to control as was the Guelph dolomite.

Preparing Break Lines

At the start of the project different methods of establishing the break line were tried by the various contractors. Not all of the rock faces in the different work sections required concrete to be placed against them; therefore, the methods used to establish the break lines varied quite a bit. The Robert Moses power plant, the intake, the conduits, and the Tuscarora pump-generating plant required concrete against a good portion of their rock walls. The canal and forebay sections did not. Some contractors used line drilling on close centers. Some used line drilling with light explosives charges placed at intervals in every second or third hole. Others used slashing, which was done after excavating in the tight; others used modified cushion blasting. Part of the wall area was prepared with holes on 1-ft., 2-ft., and 3-ft. centers which were loaded with deck charges. All the above methods were used, as well as other modifications, in an attempt to create shear planes at the "B" line. None of these methods, however, gave really clean walls where concrete was to go against them, and it was not until D. K. Holmes at the Robert Moses power plant evolved presplitting, after considerable experimentation, that superior results were obtained.

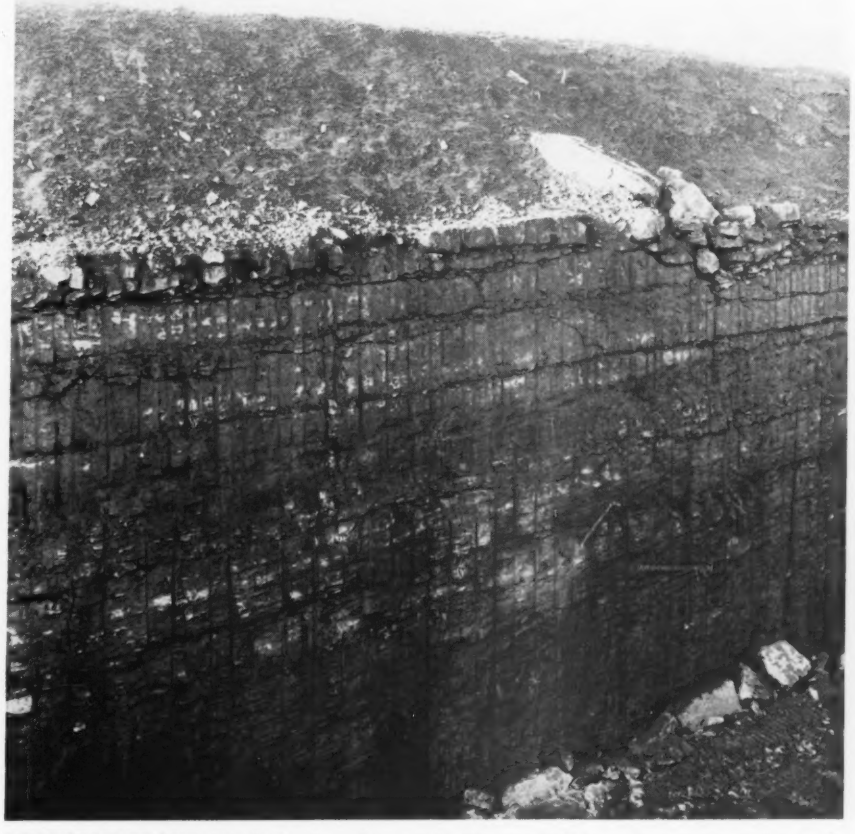
Line Drilling

Line drilling, with the drill holes being placed on the break line, was used with centers of holes varying from 4 to 9 in. Drilling these holes was a lengthy and costly operation. The break line was ragged and required quite a bit of cleaning and scaling and often the blast holes, being fired from 2½ to 4 ft. away from the line, did not break cleanly to the line nor did the line holes shear between themselves. Perhaps this raggedness was due to the nature of the formations. Bedding planes, fractures, joints, and other natural shear planes were quite prevalent in the rock. It could be that the compressive strain pulses moving outward from the blast holes, in addition to being reflected by the free surfaces of the line holes, were reflected by natural interfaces and these reflected tensile strain pulses caused rupturing of the rock beyond the break-line holes. This could be possible if there were several interfaces just past the "B" line.

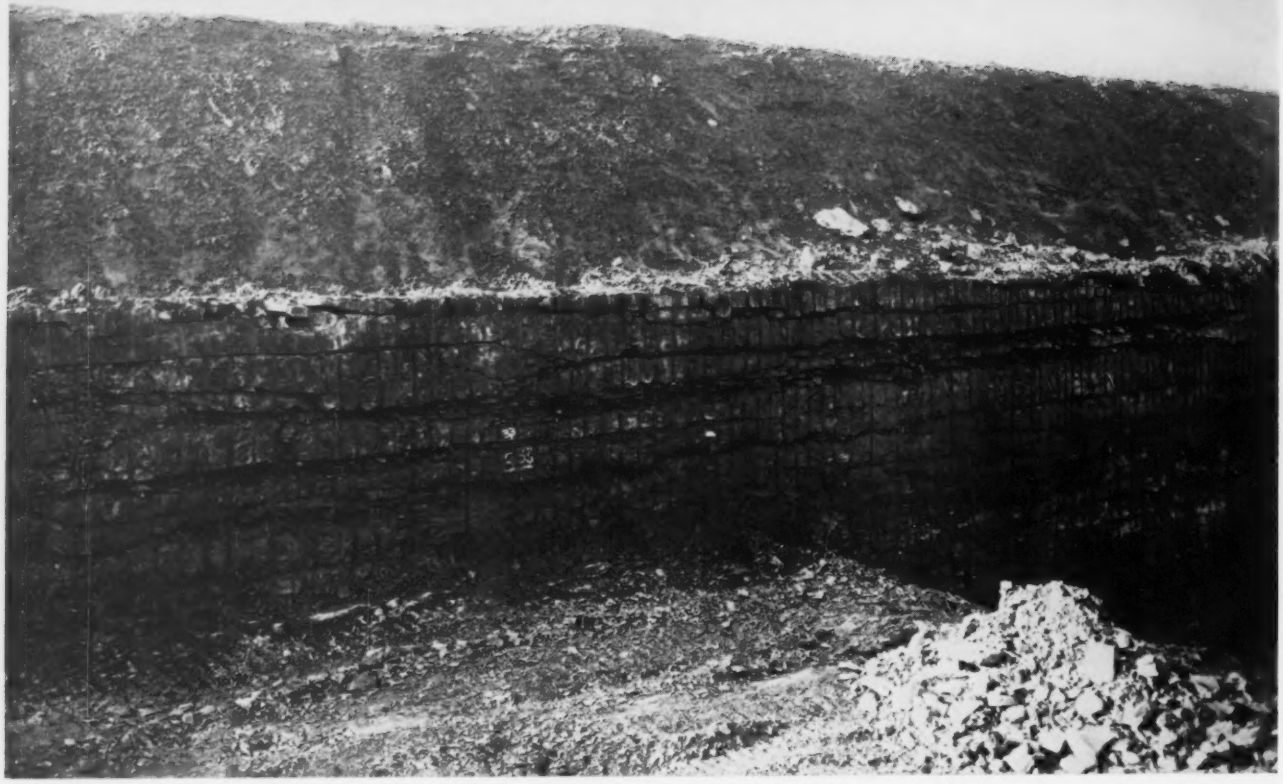
Line Drilling with Light Explosives Charges

Line holes with light explosives charges placed in the holes at regularly spaced intervals were tried. Usually the explosives charges were placed in every second or third hole. The holes were timed to fire ahead, with, or after the nearest normally charged holes of the blast pattern. Certain improvements in the condition of the break line were attained by this method of touching up the line holes. The decks were fired at times by double and triple priming. Occasionally, Primacord* was used with stemming between the charges. The above method was utilized to some extent on one of the conduit sections. Line holes were drilled as far as 2 ft. apart. Results were not satisfactory, however, since the holes did not break cleanly from one to the other. Also, priming each charge with an appropriate short-period delay was too expensive for the haphazard results obtained. When detonation of the deck charges was

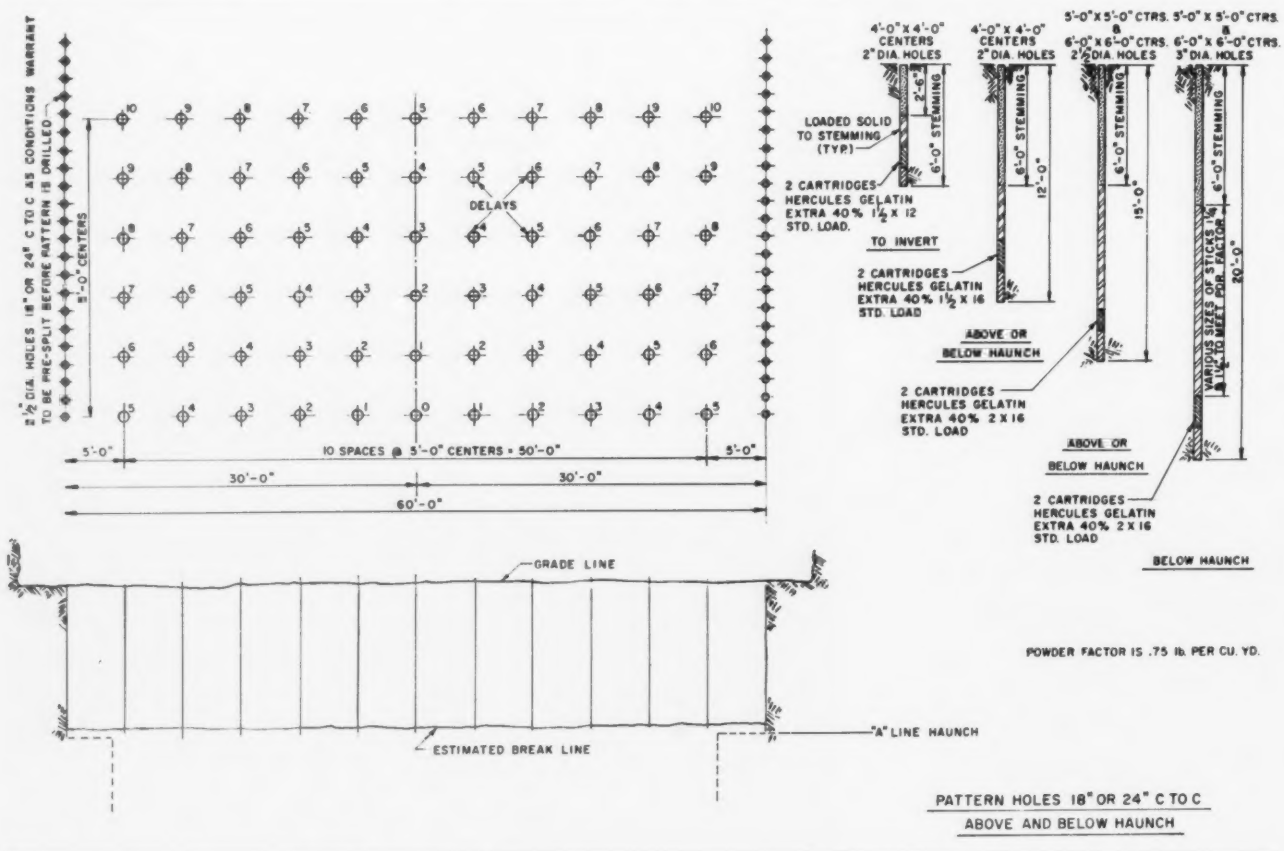
*Reg. U. S. Pat. Off. by The Ensign-Bickford Company



LOCKPORT GROUP: The bedrock geology of the Niagara Falls area is comparatively simple and consists of nearly horizontal layers of sedimentary rocks.



GUELPH DOLOMITE: The upper layer of the Lockport group is Guelph dolomite. This light gray unfossiliferous crystalline material has tight bedding planes with occasional open joints.


2½" DIA. HOLES 18" OR 24" C TO C AS CONDITIONS WARRANT TO BE PRE-SPLIT BEFORE PATTERN IS DRILLED
5'-0" CENTERS
DELAYS
5'-0"
10 SPACES @ 5'-0" CENTERS = 50'-0"
5'-0"
30'-0"
30'-0"
60'-0"
4'-0" X 4'-0" CENTERS 2" DIA. HOLES
4'-0" X 4'-0" CENTERS 2" DIA. HOLES
5'-0" X 5'-0" CTRS. & 6'-0" X 6'-0" CTRS. 2½ DIA. HOLES
5'-0" X 5'-0" CTRS. & 6'-0" X 6'-0" CTRS. 3" DIA. HOLES
LOADED SOLID TO STEMMING (TYP.)
2'-6" STEMMING
6'-0" STEMMING
2 CARTRIDGES HERCULES GELATIN EXTRA 40% 1½ X 12 STD. LOAD.
TO INVERT
12'-0"
2 CARTRIDGES HERCULES GELATIN EXTRA 40% 1½ X 16 STD. LOAD
ABOVE OR BELOW HAUNCH
15'-0"
2 CARTRIDGES HERCULES GELATIN EXTRA 40% 2 X 16 STD. LOAD
ABOVE OR BELOW HAUNCH
VARIOUS SIZES OF STICKS TO MEET POWDER FACTOR
20'-0"
2 CARTRIDGES HERCULES GELATIN EXTRA 40% 2 X 16 STD. LOAD
BELOW HAUNCH
POWDER FACTOR IS .75 lb. PER CU. YD.
GRADE LINE
"A" LINE HAUNCH
ESTIMATED BREAK LINE
PATTERN HOLES 18" OR 24" C TO C
ABOVE AND BELOW HAUNCH

NORMAL BLAST PATTERN: This diagram shows the drill pattern used in Work Section 2 to assure breakage of the intercallated massive beds encountered in the Lockport group.

done with Primacord branch lines and Primacord trunk lines, there were excessive cutoffs. These cutoffs occurred no matter whether delaying was ahead, with, or after the adjacent blast holes.

Slashing

This method is self-explanatory. Excavation was carried up to within 4 ft. of the finished wall and then slash holes were drilled on the "B" line and shot to the open excavated area. Results were good in general, but limited in depth. Slash holes were drilled on 3- and 4-ft. centers. It was in using this method that the stresses in the Guelph dolomite became evident. Blasting in the tight, no matter how carefully the holes were loaded adjacent to the break line, always seemed to open cracks beyond this line. Slashing was useful from top of rock to 30 and 40 ft. down, and gave good walls, but resulted in overexcavation and, as stated, was limited in depth.

LINE DRILLING: The results achieved by blasting using line drilling may be seen in the right-center section of this photo. Foreground shows the effect on break lines resulting from the use of normal blasting.

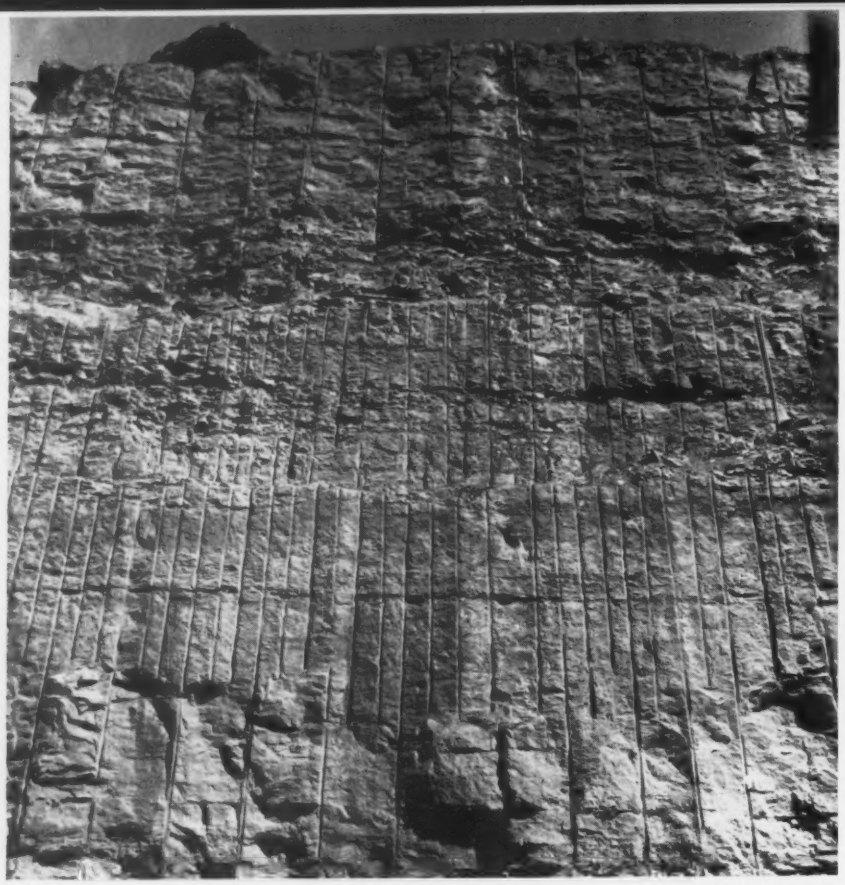
Modified Cushion Blasting

"Modified cushion blasting" was practiced almost entirely by the contractor who excavated the forebay section of the Tuscarora pump-generating plant and the open canal leading to the forebay section of the Robert Moses power plant.

This method differed from that used previously in Canada during the construction of the open conduits for the Sir Adam Beck No. 2 hydro plant, in that each of the 2½-in. holes was string-loaded with 40% ammonia gelatin being taped on 2- and 3-ft. centers for the full length of the Primacord, and the 6-in. holes were left open to act as guide holes. In Canada this method was called "cushion blasting." It consisted of drilling a series of 6¼- or 6¾-in. holes on 5-ft. centers to the desired depth. Between these holes three equally spaced 2½-in. holes were drilled to the depth of the cut being taken. This gave a pattern of 15 in. from hole center to hole center. The middle 2½-in. hole was loaded solid with explosives and the other 2½-in. holes on either side were left open to act as guide holes. Then the larger holes were string-loaded by taping either a 1⅛ by 8-in. or a 1¼ by 8-in. cartridge of ammonia gelatin to a length of Primacord equal to the depth of the smaller holes. The cartridges were taped to the Primacord on intervals of from 2 to 3 ft. Stemming was used around the string charges for the full length of the hole. The firing of the break-line holes usually was before the adjacent blast holes. Clean walls resulted, except for some raggedness around the solidly loaded center 2½-in. hole. This was not a problem, however, as no concrete was to be placed against the walls.

The contractor who used the modified cushion blasting method obtained

FOREBAY SECTION: The results of line drilling in the forebay section are vividly shown in this view near the Tuscarora pump-generator station.



TOUCHED-UP LINE DRILLING: The bottom section of the wall shows the results of touched-up line drilling on 3-ft. centers using light explosives charges. Touched-up line drilling on 1-ft. centers, with alternate holes unloaded, is shown in the center section. Top section shows slashing on 4-ft. centers.

SLASHING: In this section of the conduit, slashing on 4-ft. centers was used. Slash holes were drilled on the "B" line and shot to the open excavated area.

excellent results. As in Canada, he delayed the break-line holes in such a manner that they were fired two delay periods before the adjacent blast holes and detonation was accomplished with Primacord down lines and a trunk line. He drilled his adjacent blast holes from 2½ to 4 ft. off the break line. Results, as stated, were excellent and the contractor had no reason to try to improve his walls because no concrete was to go against them. However, he did resort to the "presplitting" method in an area near the bottom of the excavation in the Rochester shale. The proximity of the excavation to a chemical plant created some problems. Some of the machinery in the chemical plant was equipped with automatic electric circuit breakers whose switches were being thrown out by the vibrations from the regular system of blasting. When presplitting was used, vibrations were lessened and the switch-throwing problem was eliminated.

Deck Charges in Holes on 1-, 2-, and 3-ft. Centers

This method is similar to that of line drilling with light explosives charges but differs in that the holes normally were farther apart and were drilled to a much greater depth. For instance, holes on these centers were drilled from top of rock to haunch elevation, and from haunch elevation to grade. After drilling, they were backfilled with stemming to a point which corresponded with the depth of the lift being taken. As successive lifts were taken, the holes were blown out and loaded so they could be fired with the corresponding blast pattern itself. Results were good, but labor costs were high. Also, it was very difficult at times to blow the holes, and a great number of holes were lost, which tended toward tight walls and subsequent high labor costs to chip the tights.

Presplitting

Presplitting can be defined as the establishment of a free surface or shear plane in the solid by the controlled usage of explosives and blasting accessories in appropriately aligned and

(Continued on page 82)

GARDNER-DENVER MAKES THE NEWS

ALL NEW ROTA-SCREW

Portable air compressors

Gardner-Denver
engineers a proved principle into a totally new design in portable air compressors

Lowest maintenance ever!
No touching parts . . . *no* valves . . . *no* pistons . . . *no* blades to inspect or replace.

Instant compressed air!
Flip a switch to start; turn knob for immediate warm-up. Flip a switch to stop . . . *automatic blowdown.*

Pulsation-free air flow!
Continuous delivery of compressed air in a *new, efficient manner* . . . vibrationless operation.

Off-level operation!
Oil circulating system permits operation on *angle—uphill or down.*

Saves fuel!
"THRIFTMETER"® control *matches engine speed* with air demand.

All-weather operation!
Tested for *40° below* to *115° above zero.*

THREE MODELS

SP900—capacity: 900 cfm.
SP600—capacity: 600 cfm.
SP125—capacity: 125 cfm.

See why the Rota-Screw is the compressor for you

GARDNER-DENVER
QUINCY, ILLINOIS

You get new economy...new efficiency... new durability with Gardner-Denver's new Rota-Screw compressors

The Rota-Screw operates without metal-to-metal contact in the compressor chamber. Rotors are separated by timing gears, held to precise clearances between rotors and casing by heavy-duty bearings. Absence of blades, pistons, valves and other reciprocating parts extends compressor life, reduces maintenance to a trifle. Costly, pesky, blade inspection or replacement completely eliminated.

Oil flooding of rotors seals air in, removes heat of compression. Single-stage compression eliminates start-up problems—and there are no complicated interstage air passages.

SPECIAL CATERPILLAR ENGINES—Rota-Screw compressors are driven by turbo-charged, 4-cycle, 1800 rpm engines. Caterpillar-designed especially for Gardner-Denver Models SP900 and SP600 rotary screw compressors.

SHOCK-ABSORBING COUPLING—no clutch—rubber block drive provides smooth power transmission between engine and compressor.

DE-AERATING RADIATOR—removes air from the water to supply a solid stream of water for cooling the compressor oil and the engine.

FAIL-SAFE, 24-VOLT ELECTRICAL SYSTEM—if fault occurs, unit will not start . . . will shut down if running.

EASY COLD-WEATHER STARTING—engine equipped with glow plugs and ether starting aid system.

IMPROVED RUNNING GEAR—extra-heavy running gear with automotive-type steering. Heavy-duty truck tires resist punishment of rough terrain.

DRY-ELEMENT-TYPE AIR FILTERS—shortens servicing time on filters.

ADDITIONAL IMPORTANT FEATURE—units are designed for accessibility . . . featuring *grip handles* and *step plates* for top service.

THREE MODELS

Model SP900 . . . 900 cfm

Model SP600 . . . 600 cfm

Model SP125 . . . 125 cfm
(Turn wheel optional.)

How Rota-Screw compresses air

A time-proved principle forms the basis for Gardner-Denver Rota-Screw compressors. As air enters the intake port, it is drawn into the space between lobes of two helical rotors. The revolving rotors force the air into succeedingly smaller interlobal spaces, thus compressing the air in a single stage until full compression is reached at the outlet port. As this air is expelled, the next groove comes into line with the outlet port to assure a smooth air flow without pulsation —cycle after cycle. Compressor operates without vibration . . . air tool performance improves.

Water-oil cooling system

Gardner-Denver's effective water-oil cooling system provides constant operating temperature for both engine and compressor under all climatic conditions from –40° to +115°. Discharge air temperature is normally kept between 170° F. and 190° F. with average operating conditions at 100 psi. Combined oil receiver and separator preserves oil supply, cleans air of oil.

SPECIFICATIONS

Model	SP900	SP600	SP125
Capacity at 100 psi	900 cfm	600 cfm	125 cfm
Engine	Caterpillar D343T	Caterpillar D333T	Continental F-266
Length	13′7″	12′1½″	12′1″
Width	6′8″	6′	5′4½″
Height	8′½″	7′	5′5″
Track	5′8″	5′	4′8″
Turning radius	12′	8′	—
Net weight	13,775 lb.	9,150 lb.	2,980 lb.

For complete specifications, write for Bulletin SP-1.

EQUIPMENT TODAY FOR THE CHALLENGE OF TOMORROW

GARDNER - DENVER

Gardner-Denver Company, Quincy, Ill.—Offices in principal U.S., Canadian and Mexican cities.
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LITHO IN U. S. A.

MODIFIED CUSHION BLASTING: Here the 2½-in. holes were string-loaded with 40% Hercules® Gelatin Extra taped on 2- and 3-ft. centers for the full length of the Primacord. The 6-in. holes were left open to act as guide holes.

spaced drill holes. It was through necessity that this method was developed, or let us say refined, to such a degree on the Niagara Power Project. To our knowledge, presplitting had not been used anywhere before on the scale that it was used at Niagara.

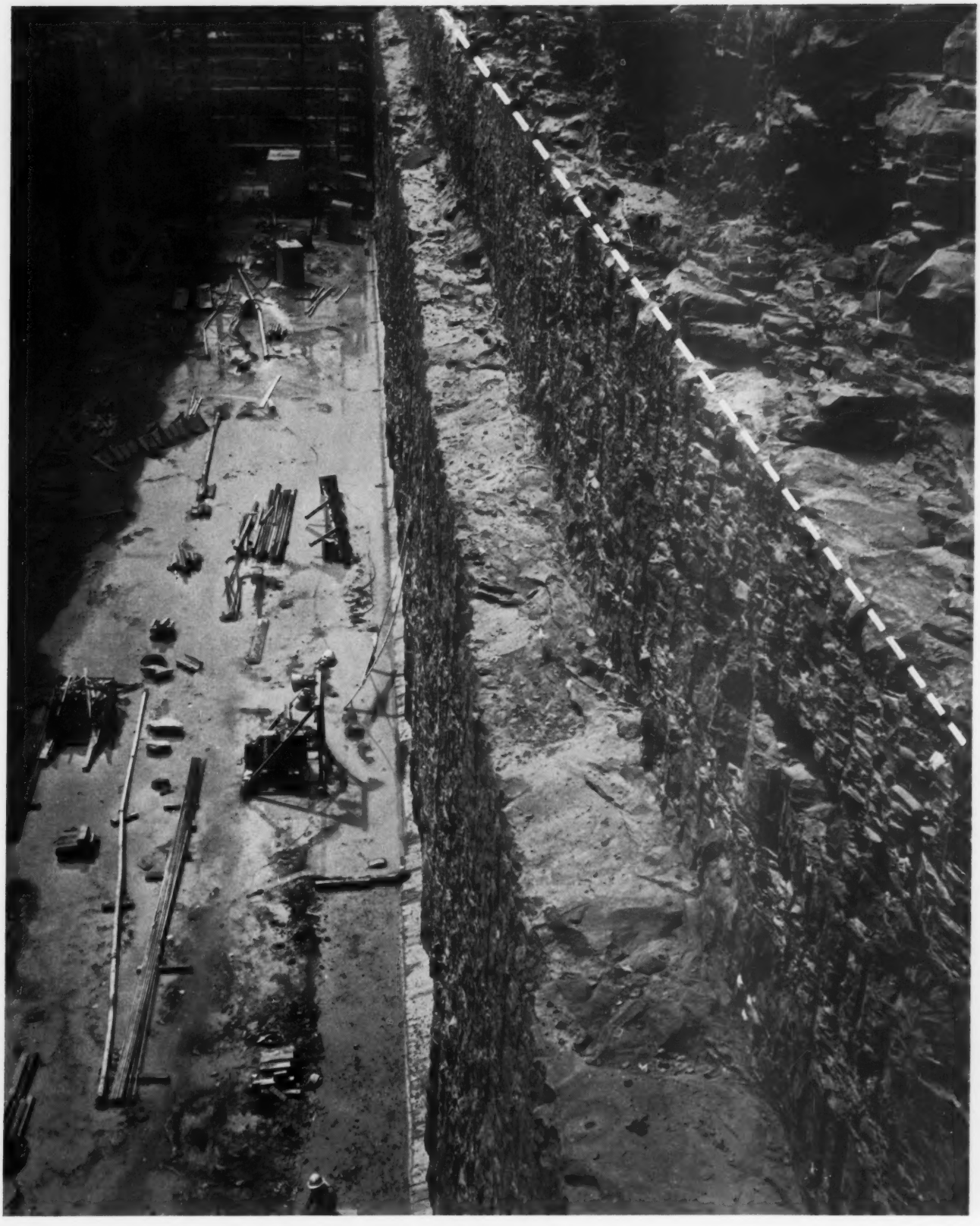
In some respects, this method of preparing a break line is similar to "smooth blasting," as used in Sweden, or "perimeter blasting," as used in Canada. It differs, however, to the extent that smooth blasting and perimeter blasting are accomplished during the same time period when a blast pattern is being fired, while presplitting is accomplished prior to the drilling of the blast pattern. Weeks can pass after presplitting is done, in the solid, before blast patterns for excavation are drilled. This method did not seem to have any depth limitations other than those imposed by drilling and keeping the drill holes from drifting too far from plumb. The maximum depth that was drilled at Niagara, and presplit, and which stayed within the 6-in. tolerance was 64 ft.

Presplitting, as developed in its initial stages, consisted of taping fractional portions of 1¼ by 8-in. 40% ammonia gelatin to lengths of Primacord equal to the depths of the holes being split. These small charges were taped to the Primacord at varying intervals of from 4 to 8 in. The diameter of these drill holes, in general, was from 2½ to 3 in. The holes were drilled on centers of approximately 12 in. Detonation was with Primacord trunk lines or with individual priming at each down line with short-period delay caps. Instantaneous detonation with Primacord trunk lines gave the best results. Experimentation was done with loading every other hole and with loading and firing every hole. The loading of each hole gave a cleaner face. Stemming was used in all loaded holes.

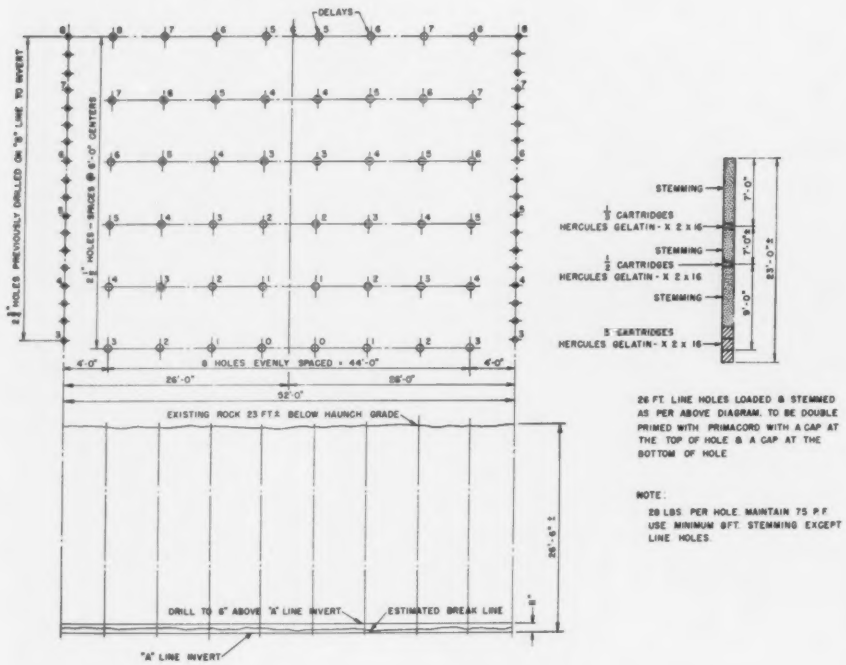
The results obtained at the Robert Moses power plant indicated that this method of preparing break lines should be tried in other areas, particularly on the conduit sections of the waterways which had millions of square feet of area against which concrete had to be placed. Other than the establishment of a clean shear plane against which to place concrete, it was thought that perhaps by presplitting, some other stress in the Lockport group could be alleviated. To a certain degree this proved to be the case.

The contractor in Work Section No. 2 decided to experiment with presplitting his break lines after D. K. Holmes had proved it could be done. Initially, the same pattern was followed as that used on the Robert Moses powerhouse excavation, namely, fractional charges and 12-in. centers with 2½-in. holes drilled on the back side of the "B" line. Collaring the holes with the leading edge of the bit on the back side of the "B" line gave better results insofar as drift of drill holes was concerned. The holes stayed within the 6-in. tolerance between the "A" line and the "B" line

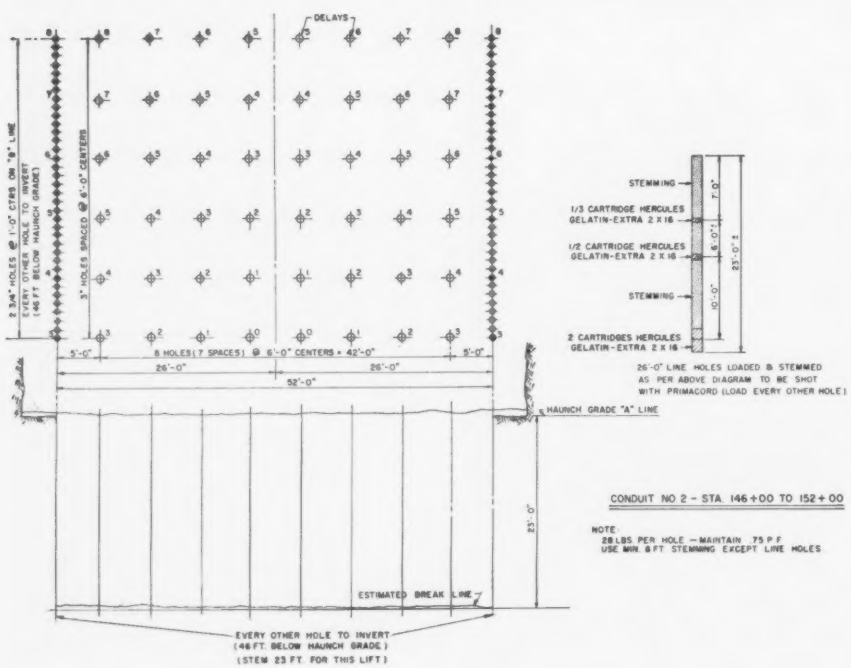
DECK CHARGES: Holes were drilled on close centers from top of haunch to invert. After drilling, the holes were back filled to the level of the lift being taken. As each successive lift was taken the holes were blown out and loaded for each lift. Considerable chipping was found to be necessary in this area.



FROM TOP OF HAUNCH: Another view from the top of the haunch of the conduit section. Holes were drilled on close centers, back filled, and then blown out and loaded to be blasted according to prescribed blast patterns. Dotted line separates presplitting from normal blasting.


DELAYS
HOLES PREVIOUSLY DRILLED ON "B" LINE TO INVERT
2½" HOLES - SPACED @ 6'-0" CENTERS
8 HOLES EVENLY SPACED = 44'-0"
4'-0"
26'-0"
52'-0"
EXISTING ROCK 23 FT.± BELOW HAUNCH GRADE
DRILL TO 6" ABOVE "A" LINE INVERT
ESTIMATED BREAK LINE
"A" LINE INVERT
STEMMING
½ CARTRIDGES HERCULES GELATIN - X 2 x 16
STEMMING
½ CARTRIDGES HERCULES GELATIN - X 2 x 16
STEMMING
5 CARTRIDGES HERCULES GELATIN - X 2 x 16
7'-0"
7'-0"
9'-0"
23'-0"±
26 FT. LINE HOLES LOADED & STEMMED AS PER ABOVE DIAGRAM. TO BE DOUBLE PRIMED WITH PRIMACORD WITH A CAP AT THE TOP OF HOLE & A CAP AT THE BOTTOM OF HOLE
NOTE:
28 LBS. PER HOLE MAINTAIN 75 P.F. USE MINIMUM 8FT. STEMMING EXCEPT LINE HOLES

TOUCHED-UP LINE HOLES: This plan shows the distribution of the explosives on Primacord where line drilling with light explosives charges was used. The Primacord was primed with an electric blasting cap at both top and bottom of hole.


DELAYS
2 3/4" HOLES @ 1'-0" CTRS ON "B" LINE
(EVERY OTHER HOLE TO INVERT (46 FT BELOW HAUNCH GRADE))
3" HOLES SPACED @ 6'-0" CENTERS
8 HOLES (7 SPACES) @ 6'-0" CENTERS = 42'-0"
5'-0"
5'-0"
26'-0"
26'-0"
52'-0"
HAUNCH GRADE "A" LINE
ESTIMATED BREAK LINE
EVERY OTHER HOLE TO INVERT (46 FT. BELOW HAUNCH GRADE) (STEM 23 FT. FOR THIS LIFT)
23'-0"
STEMMING
1/3 CARTRIDGE HERCULES GELATIN-EXTRA 2 X 16
1/2 CARTRIDGE HERCULES GELATIN-EXTRA 2 X 16
STEMMING
2 CARTRIDGES HERCULES GELATIN-EXTRA 2 X 16
7'-0"
6'-0"±
10'-0"
23'-0"±
26'-0" LINE HOLES LOADED & STEMMED AS PER ABOVE DIAGRAM TO BE SHOT WITH PRIMACORD (LOAD EVERY OTHER HOLE)
CONDUIT NO 2 - STA. 146+00 TO 152+00
NOTE:
28 LBS PER HOLE - MAINTAIN 75 P.F.
USE MIN. 8 FT STEMMING EXCEPT LINE HOLES

BREAK-LINE PREPARATION: In this method of preparing break lines, holes on 2-ft. centers were drilled approximately 23 ft. deep to invert. The in-between holes on 1-ft. centers were not loaded with explosives.

when collared in this fashion. The initial pattern was successful but proved to be too slow and required too much drilling to keep up with excavation progress. It was also evident immediately that presplitting in the solid increased excavation progress because there was little or no scaling that had to be done before the next lift could be taken. Therefore, the hole spacings were increased, the size of the charges on the Primacord down lines was increased, and the interval of separation of the charges was increased.

Eventually, holes were drilled on 2-ft. centers and a 1¼ by 4-in. section of 40% gelatin extra was taped on a length of reinforced Primacord, corresponding to the depth of the hole, with the centers of the charges being 12 in. apart. Each hole was loaded and stemmed completely with minus ⅜-in. clean stone chips. Sand was tried but it had a tendency to bridge. The stemming was worked around the taped charges by holding the end of the Primacord in the center of the hole and working it up and down. Several hundred lineal feet of conduit on both sides were fired simultaneously with electric blasting caps hooked up at each end of the trunk lines.

Presplitting Produced Many Beneficial Results

The contractor in Work Section No. 2, who used presplitting exclusively after other methods proved to be too inaccurate and expensive, was able to increase his rock excavation from 130,000 to 200,000 cu. yd. per month. This was done in quite restricted quarters. The first 60 ft. in depth of the conduits was 60 ft. wide, and the last 46 ft. in depth was only 52 ft. wide. Most of this excavation was done with 6-cu. yd. shovels.

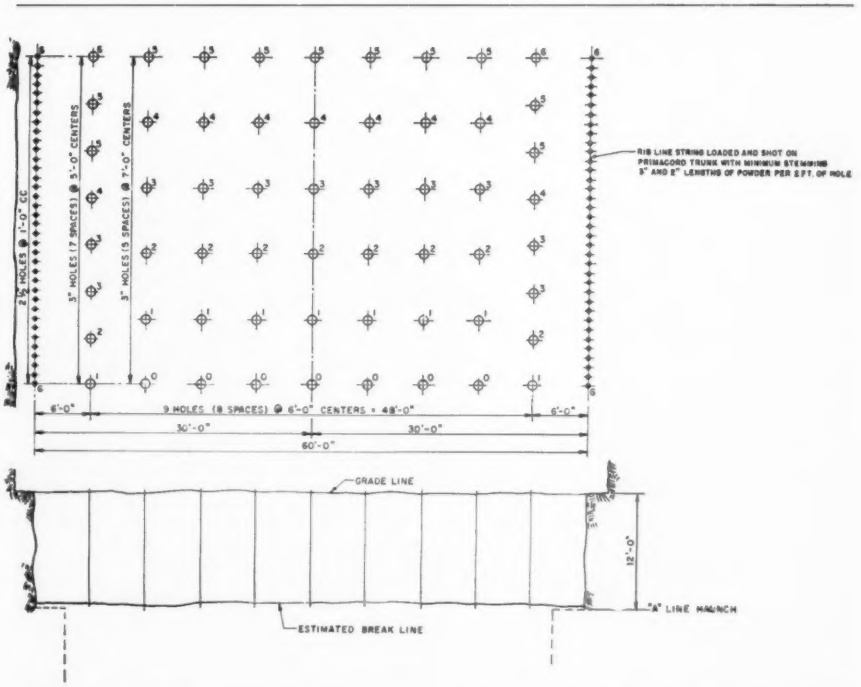
Prior to presplitting, it took 24 men working a 12-hr. shift to clean and scale a distance of 100 ft. per week on both sides of one conduit above the haunch. After presplitting was put in general practice, 12 men working the same shift time were able to clean and scale 1,000 ft. a week on both sides of one conduit above the haunch. Below the haunch, chipping wall tights, prior to presplitting, required

PRESPLIT AND NORMAL BLASTING: The clean, smooth face produced by the presplit method of blasting is vividly shown in the lower part of this photo. Normal blasting with its ragged face and overbreak can be seen at the top of the conduits.

59 men. After presplitting, six men were all that were required. Both shift times were the same.

Significant savings in concrete were noted on Work Sections Nos. 2 and 3 where presplitting was used. The walls from 12 ft. above the haunch to grade were evenly sheared and overbreak was negligible.

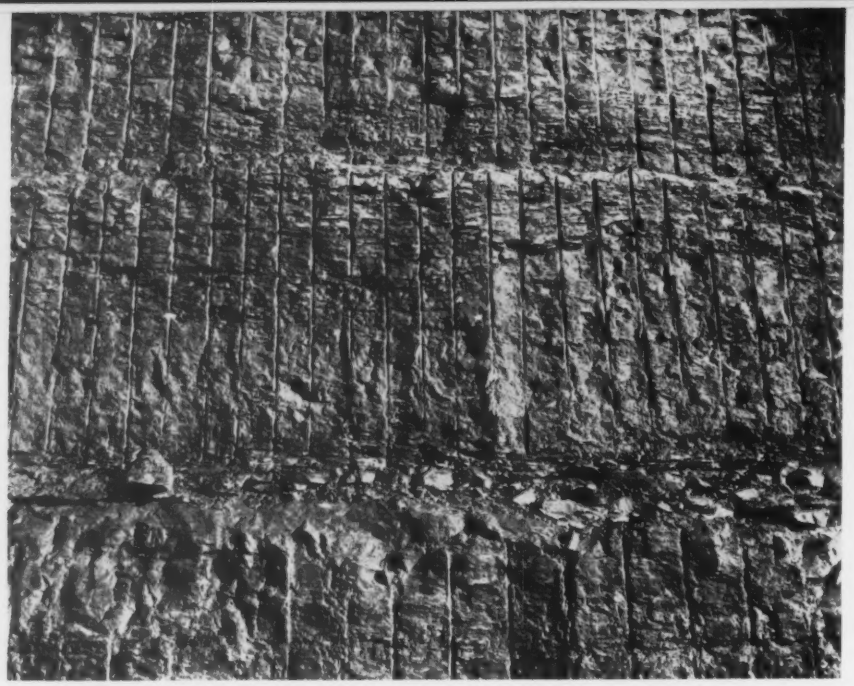
A dewatering pump shaft was put down in the transition stage between the parallel conduits on Work Section No. 3 in which the establishment of the break line was accomplished with presplitting. This was done with three presplit lifts by setting back far enough on the first lift so that on the last lift the presplit line would fall on the "B" line. No time was wasted in barring down, scaling, or supporting any section of this shaft while it was being sunk.


2½" HOLES @ 1'-0" CC
3" HOLES (7 SPACES) @ 5'-0" CENTERS
3" HOLES (5 SPACES) @ 7'-0" CENTERS
RIB LINE STRING LOADED AND SHOT ON PRIMACORD TRUNK WITH MINIMUM STEMMING 3" AND 8" LENGTHS OF POWDER PER 2 FT. OF HOLE
6'-0"
9 HOLES (8 SPACES) @ 6'-0" CENTERS = 48'-0"
6'-0"
30'-0"
30'-0"
60'-0"
GRADE LINE
12'-0"
"A" LINE HAUNCH
ESTIMATED BREAK LINE

EXPERIMENTAL PRESPLITTING: This diagram shows the initial stages of experimentation in presplitting. This procedure is similar to "smooth or perimeter" blasting except that presplitting is accomplished prior to the drilling of the blast pattern.

Safety

The elimination of overbreak by the establishment of clean shear planes



PRESPLIT FACE: In this close-up of the face made by presplitting, it is difficult to identify the areas where the explosives were detonated in the holes.

CONDUIT WALL: This nicely sheared conduit wall is the result of the presplitting technique. There will be a minimum amount of scaling, and less concreting will be needed.

with presplitting greatly reduced the hazard from falling rock from the walls or rims of the excavations, where it was utilized. The reduction in the number of men needed for scaling, chipping, and cleaning the rock faces naturally reduced the man-hours of exposure and significantly reduced the accident rate. Also, the workers in the hole were protected during both excavation and concreting and were able to apply themselves to their work assiduously because they would keep both eyes on their work and not have one eye on the wall and one on their work—an excellent way to get hurt.

Quantitative Treatment

Now we will turn to quantitative considerations in order to be able to predict some of the values of the parameters involved in presplitting. Consider a piece of rock containing two cylindrical drill holes of radius A and whose axes are a distance D apart. Assume each hole is simultaneously subjected to an explosive pulse beginning at time $T = o$. A cylindrical wave front proceeds out radially from each hole with a velocity of U ft./sec. where U is the speed of sound in the rock. After a time $\frac{D}{2U}$ the wave fronts meet between the two holes and this region is subjected to a compressive pressure whose peak magnitude is given by

$$P_o = P_b \sqrt{A/R}\, e^{-kT}$$

where P_b is the bore hole pressure, R is the radial distance, and k is a time constant.*† Since T equals $\frac{D}{2U}$ we have

$$P_o = P_b \sqrt{2A/D}\, e^{-kD/2U}$$

In a direction tangential to the wave front the rock is subjected to a stress of peak magnitude

$$E\epsilon_o = -\sigma P_b \sqrt{2A/D}\, e^{-kD/2U}$$

where E is Young's modulus and σ is Poisson's ratio.† The total stress parallel to the cylinder axes is reduced by the compressive force of the burden. The other tangential component is undiminished by the burden and tends to

produce cracks between the holes, assuming that $E\varepsilon_o$ is greater than the tensile strength of the rock.

Now consider a point on a plane parallel to the axes and midway between them. Let this plane be perpendicular to the plane determined by the cylinder axes. Draw a line radially from one of the axes through the point (see Figure A). Suppose the line makes an angle with the line AB. Then the compressive force at this point at the time the wave fronts meet has a peak magnitude given by

$$P_o = \cos\theta \cdot P_b \cdot \frac{}{\sqrt{2A\cos\theta/D}}\, e^{-kD/2U\cos\theta}$$

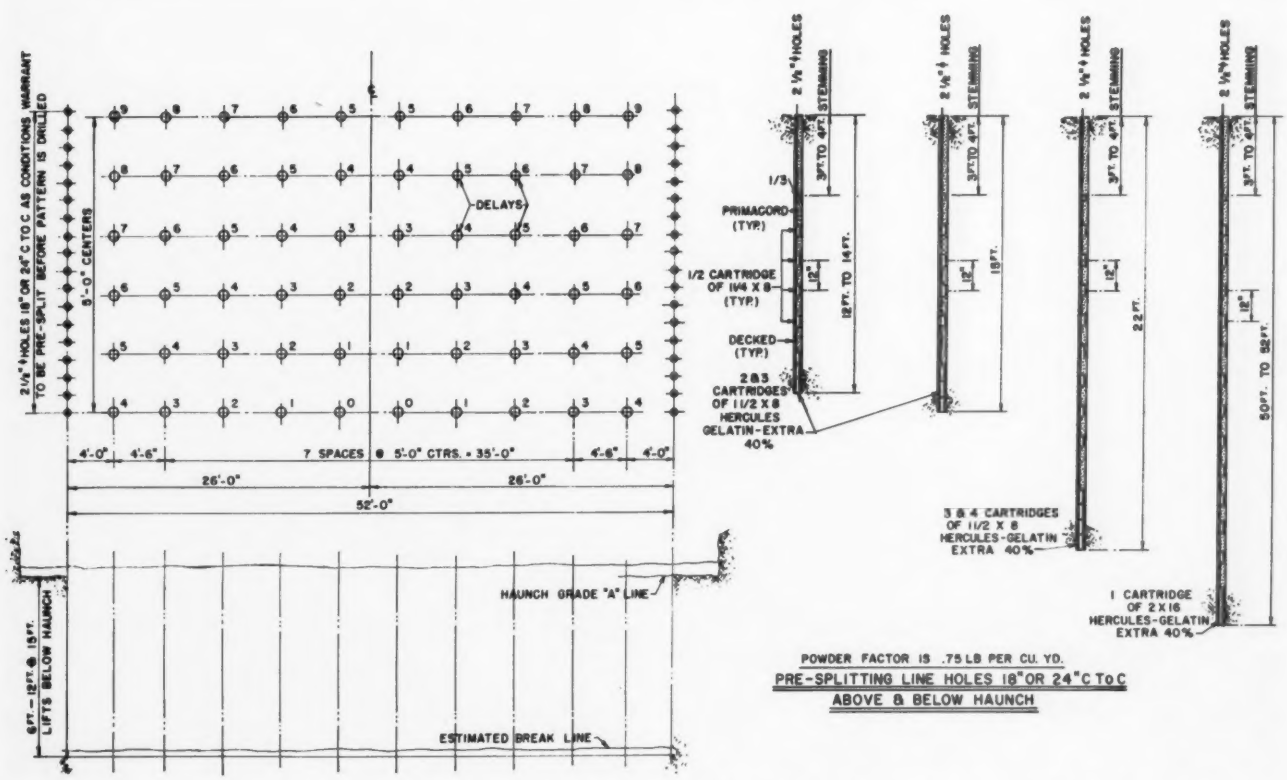
and the tangential strain is given by

$$\varepsilon_o = -\frac{\sigma}{E}\cos\theta \cdot P_b \cdot \frac{}{\sqrt{2A\cos\theta/D}}\, e^{-kD/2U\cos\theta}$$

Obviously the strain is reduced for points not on a line connecting the two axes for the following reasons: 1. the ratio

$$r = -kD/2U\cos\theta < -kD/2U$$

LOADING: The line of Primacord with the fractional cartridge of Hercules 40% Gelatin Extra taped to it at regular intervals is lowered into the hole. The hole is then filled with minus ¾ clean stone chips and the Primacord connected to the trunk line serving the rest of the pattern.


2 1/8" HOLES 18" OR 24" C TO C AS CONDITIONS WARRANT TO BE PRE-SPLIT BEFORE PATTERN IS DRILLED
5'-0" CENTERS
DELAYS
4'-0"
4'-6"
7 SPACES @ 5'-0" CTRS. = 35'-0"
26'-0"
52'-0"
HAUNCH GRADE "A" LINE
6 FT - 12 FT. @ 15 FT. LIFTS BELOW HAUNCH
ESTIMATED BREAK LINE
2 1/8" HOLES
STEMMING
3 FT. TO 4 FT.
1/3
PRIMACORD (TYP.)
1/2 CARTRIDGE OF 1 1/4 X 8 (TYP.)
DECKED (TYP.)
2 & 3 CARTRIDGES OF 1 1/2 X 8 HERCULES GELATIN-EXTRA 40%
12 FT. TO 14 FT.
18 FT.
22 FT.
50 FT. TO 52 FT.
3 & 4 CARTRIDGES OF 1 1/2 X 8 HERCULES-GELATIN EXTRA 40%
1 CARTRIDGE OF 2 X 16 HERCULES-GELATIN EXTRA 40%
POWDER FACTOR IS .75 LB PER CU. YD.
PRE-SPLITTING LINE HOLES 18" OR 24" C TO C
ABOVE & BELOW HAUNCH

PRESPLITTING: This plan shows the spacing of the explosive charges on the Primacord line that was found most effective in presplitting line holes both above and below the haunch.

and thus

$$e^{-r} < e^{-kD/2U}$$

2. $2A \cos\theta < 2A$ and thus

$$\sqrt{2A \cos\theta/D} < \sqrt{2A/D}$$

3. $\cos\theta \cdot P_b < P_b$. Since the compressive strength of many common rocks is of the order of thirteen to sixteen times greater than the tensile strength, it is possible to produce no crushing of the rock at the point of detonation and still produce cracks connecting the two cylindrical holes, provided the distance between the holes is small enough.

In addition to the strain described above, there will be a strain produced by an increase in the radius of the cylindrical holes. The increase in radius from A to $A+\Delta R$ increases the circumference of the cylinder from $2\pi A$ to $2\pi (A+\Delta R)$ so that the increase in circumference is

$$\Delta C = 2\pi \Delta R$$

This strain tends to produce radial cracks about the cylindrical holes in all directions. Note also that where the wave fronts meet, the forces tending to produce particle displacement have equal and opposite components parallel to the line joining the cylinder axes and hence the resultant force tending to produce particle displacement is given by ND in the figure and acts perpendicular to this line. Thus the result of the wave fronts reinforcing between the holes will be to increase the length of these cracks to the point where they actually meet between the holes. The magnitude of the force ND tending to produce particle displacement is given by

$$F = 2 \sin\theta \cdot P_b \cdot \sqrt{2A \cos\theta/D}\, e^{-kD/2U \cos\theta}$$

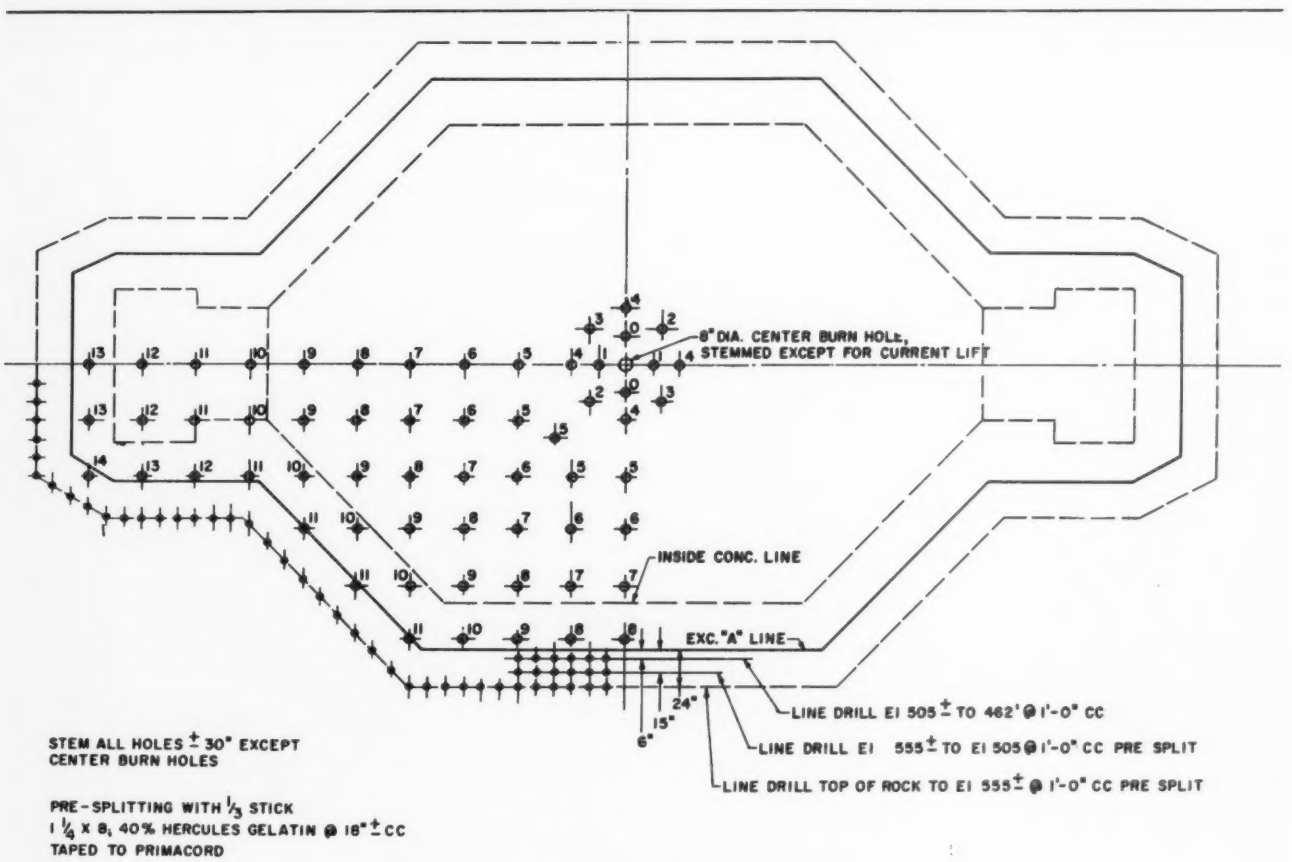
In calculating the volume of explosive to be placed in each hole it is necessary to keep in mind the equation relating bore hole pressure and detonation pressure, in particular,

$$P_b = \frac{V_e}{2V_c} \cdot P_o$$

where P_b is bore hole pressure,* V_e is volume of explosive, and V_c is volume of explosive chamber. Care must be used in calculating V_c since this is not the total volume of the hole, but the volume of a cylinder of height h and radius a where h is the distance be-

HELICOPTER VIEW: The intricate break line required by the shaft specifications was easily established by the presplit method of blasting.

IN THE SHAFT: Looking down the shaft to the bottom of the first 49-ft. presplit break line. The offset for the second presplit line may be seen in the left foreground. The entire periphery of each presplit pattern was fired at one time.


8" DIA. CENTER BURN HOLE, STEMMED EXCEPT FOR CURRENT LIFT
INSIDE CONC. LINE
EXC. "A" LINE
24"
15"
6"
LINE DRILL EI 505 ± TO 462' @ 1'-0" CC
LINE DRILL EI 555 ± TO EI 505 @ 1'-0" CC PRE SPLIT
LINE DRILL TOP OF ROCK TO EI 555 ± @ 1'-0" CC PRE SPLIT
STEM ALL HOLES ± 30" EXCEPT CENTER BURN HOLES
PRE-SPLITTING WITH 1/3 STICK 1 1/4 X 8, 40% HERCULES GELATIN @ 18" ± CC TAPED TO PRIMACORD

TYPICAL PATTERN EACH 12 FT. LIFT

SHAFT DIAGRAM: Plan shows drilling and loading details required for presplitting to assure even walls on the complex shaft operation.

tween centers of successive charges in the hole. Given the equation shown, V_e must be chosen so that

$$P_b < S_c$$

where S_c is the compressive strength of the rock. Figure B shows results obtained when this equation is satisfied and Figure C shows results when $P_b > S_c$.

The equations above are not useful in practice since estimations of the decay constant k are not available. W. I. Duvall‡ has suggested that the decay factor may be replaced by

$$\tau = e^{-\alpha R/c}$$

where R is the radial distance, c is the radius of the charge, and α is an absorption constant. The value of α for a granite gneiss is given for various explosives.§ All are very close to .03 regardless of the explosive.

Let us consider as an example how the various quantities might be determined on the basis of the equations given. The constants in our equation are naturally determined by the nature of the rock itself. Suppose the compressive strength of a certain rock is 30,000 p.s.i. and its tensile strength is 500 p.s.i. Let the charges be located in holes 4 in. in diameter and suppose the holes are 2 ft. apart. Suppose we wish to put the explosive on 1-ft. centers and that the diameter of the charge is 2 in. The quantity V_c is given by

$$V_c = \pi A^2 h.$$

Assume that the detonation pressure of the explosive is 10^6 p.s.i. Then we must have

$$P_b = \frac{V_e \cdot 10^6}{2 \cdot \pi / 36} < 3 \times 10^4$$

$$V_e < \frac{2\pi \cdot 3 \cdot 10^4}{36 \times 10^6} = \frac{6\pi \times 10^{-2}}{36} \approx .005 \text{ cu. ft.}$$

Since $C = 1/12$ ft., then

$$L \cdot \pi / 144 < \frac{6\pi \times 10^{-2}}{36}$$

$$L < \frac{6 \cdot 144 \cdot 10^{-2}}{36} = 24 \times 10^{-2} = .24 \text{ ft.} \approx 3 \text{ in.}$$

It should be mentioned in passing that the experiments performed by D. R. Grine and G. R. Fowles‖ indicate that the dynamic compressive strength of rock may be ten to twelve times greater than the static compressive strength; therefore the above calculation is not as critical as the result implies.

Finally, we want the tensile stress $E\varepsilon_o > 500$ p.s.i. With $R = 1$ ft., $\alpha = .03$ and $C = 1/12$ ft.,

$$e^{-\alpha R/C} = e^{-.36} \approx .7$$

$$\sqrt{2A/D} = \sqrt{A} = \frac{1}{\sqrt{6}} \approx .4$$

and hence

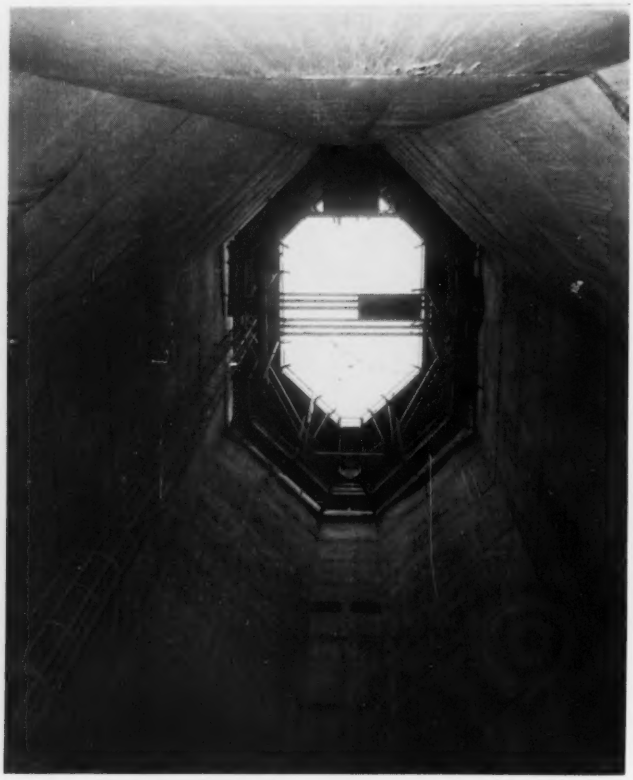
$$E\varepsilon_o = .84 \times 10^4 \times \sigma$$

σ for most rock is between .1 and .3 so that in the worst case we have

$$E\varepsilon_o = .84 \times 10^3 = 840 \text{ p.s.i.} > 500 \text{ p.s.i}$$

In conclusion, it appears feasible that collars of shafts and excavations,

FROM THE BOTTOM: The effectiveness of the presplit blasting technique is shown by this dramatic photo which clearly defines the relatively smooth side walls of the shaft.



FINISHED SHAFT SECTION: A section of the shaft where concreting has been completed. Presplitting effected a considerable saving to the contractor in the amount of surplus concrete needed.

COMPRESSIVE STRENGTH: Because of their greater ratio of compressive strength to tensile strength, many rocks can be presplit without a crushing effect, provided the distances between drill holes are not too great.

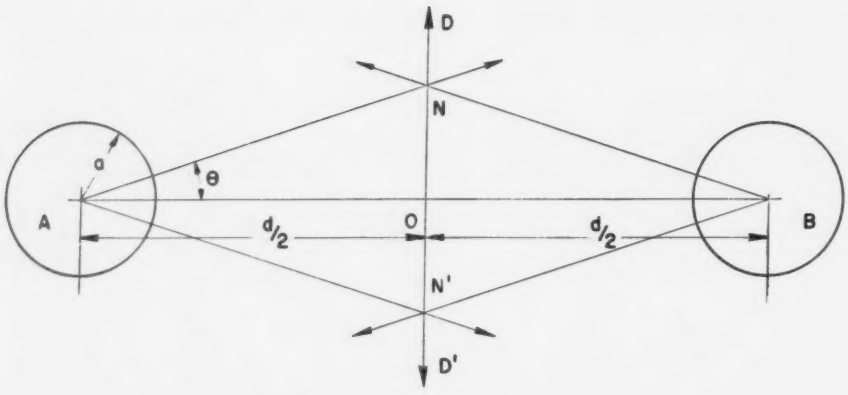


FIGURE A: A and B represent cylindrical drills with axes a distance d apart. N and N¹ represent contact points of the wave fronts generated by simultaneous explosions in A and B. D and D¹ represent the forces tending to produce particle displacement.

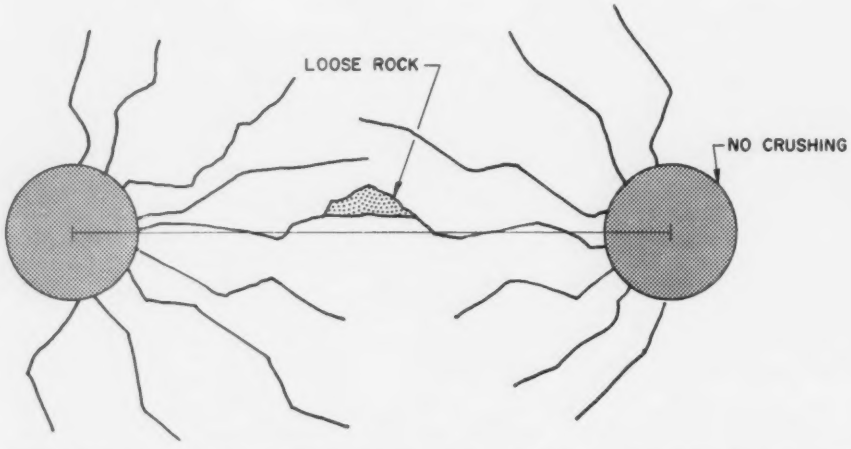


FIGURE B: This figure shows the linking of radial cracks between drill holes. The charges were sufficient to obtain this linkage without crushing rock in the walls of the drill holes.

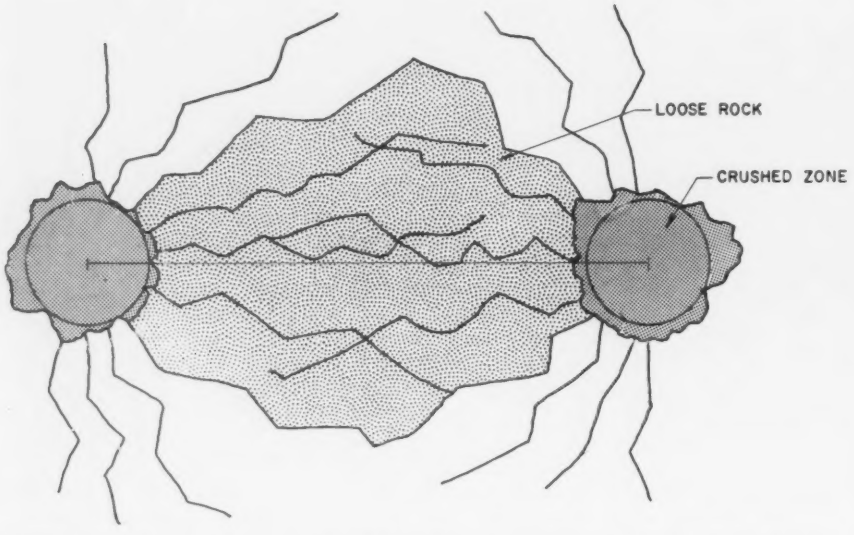


FIGURE C: The linkage of several radial cracks at a considerable distance off the line connecting the axes of the drill holes is shown in this figure. In this case, not only was there excessive linkage, but also the familiar crushed zone appeared, indicating a bore hole pressure in excess of the compressive strength of the rock.

where concrete is to be placed against the walls, can be prepared by presplitting. Further, the method can be applied to railroad cuts, highway cuts, tunnel portals, intakes to portals, underground excavations, spillways, flumes, and any number of excavations which require clean rock faces. Other applications can be around building excavations, quarries, machine foundations, bridge piers, etc., where transmission of vibrations to nearby structures by normal blasting must be reduced to a permissible ER ratio.¶ In these applications, presplitting has established a free surface, or interface, between the area occupied by the excavation blast holes and the area where it is necessary to have a permissible ER ratio. This interface, where the number of pounds of explosives per delay interval is required to be held to a certain limit, will give the user of explosives the opportunity of increasing the explosive charge per delay period in excavation blast holes and still remain under the permissible ER ratio. Considerable savings can be effected in this way. The frequency of blasting can be reduced in populated areas and the nuisance aspect of blasting greatly minimized.

REFERENCES

*Kumao Hino, *Theory and Practice of Blasting*, Nippon Kayaku Co., Ltd., 1959 (first edition), p. 100, p. 88.

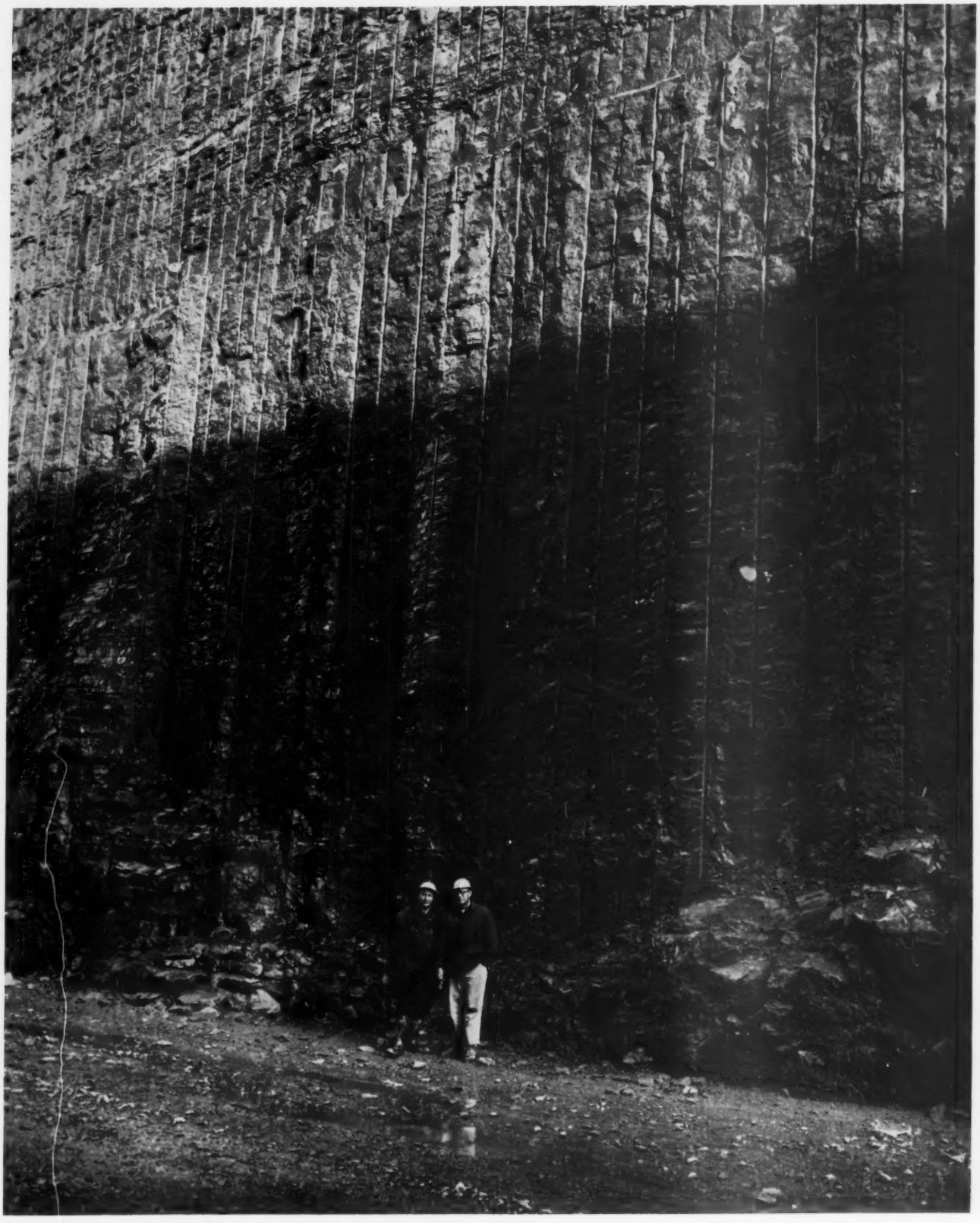
†H. & B. S. Jeffreys, *Methods of Mathematical Physics*, Cambridge University Press, 1950 (second edition), p. 596, p. 101.

‡W. I. Duvall, Telephone Conversation.

§W. I. Duvall et al., "Propagation of Peak Strain and Strain Energy in Explosion-Generated Strain Pulses in Rock," *Quarterly of the Colorado School of Mines*, Vol. 54, No. 3, July, 1959.

‖D. R. Grine and G. R. Fowles, "The Attenuation of Shock Waves in Solid Materials with Seismic Applications," *Quarterly of the Colorado School of Mines*, Vol. 54, No. 3, July, 1959.

¶F. J. Crandell, *Ground Vibration Due to Blasting and Its Effect Upon Structures*, Liberty Mutual Insurance Co.



PRESPLITTING RESULTS: A nice clean smooth face. Holes drilled from haunch elevation to invert, approximately 46 ft. Rough area at bottom, which is caused by loads not reaching bottom, is removed by light explosive charges loaded in alternate holes.

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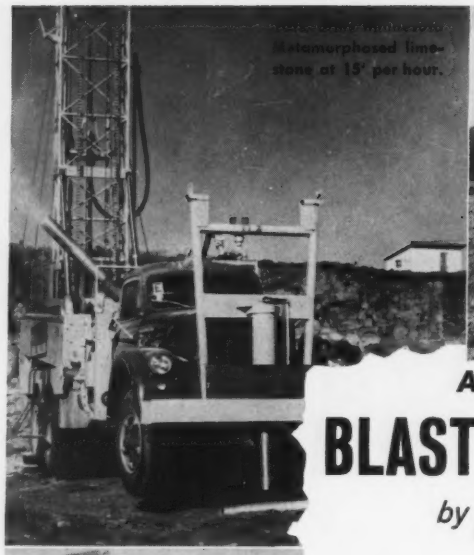
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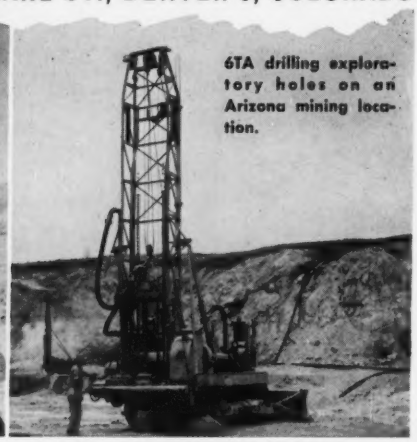
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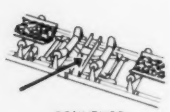

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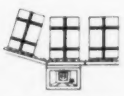

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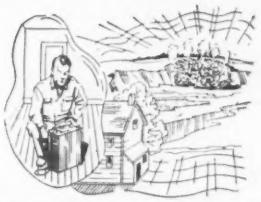

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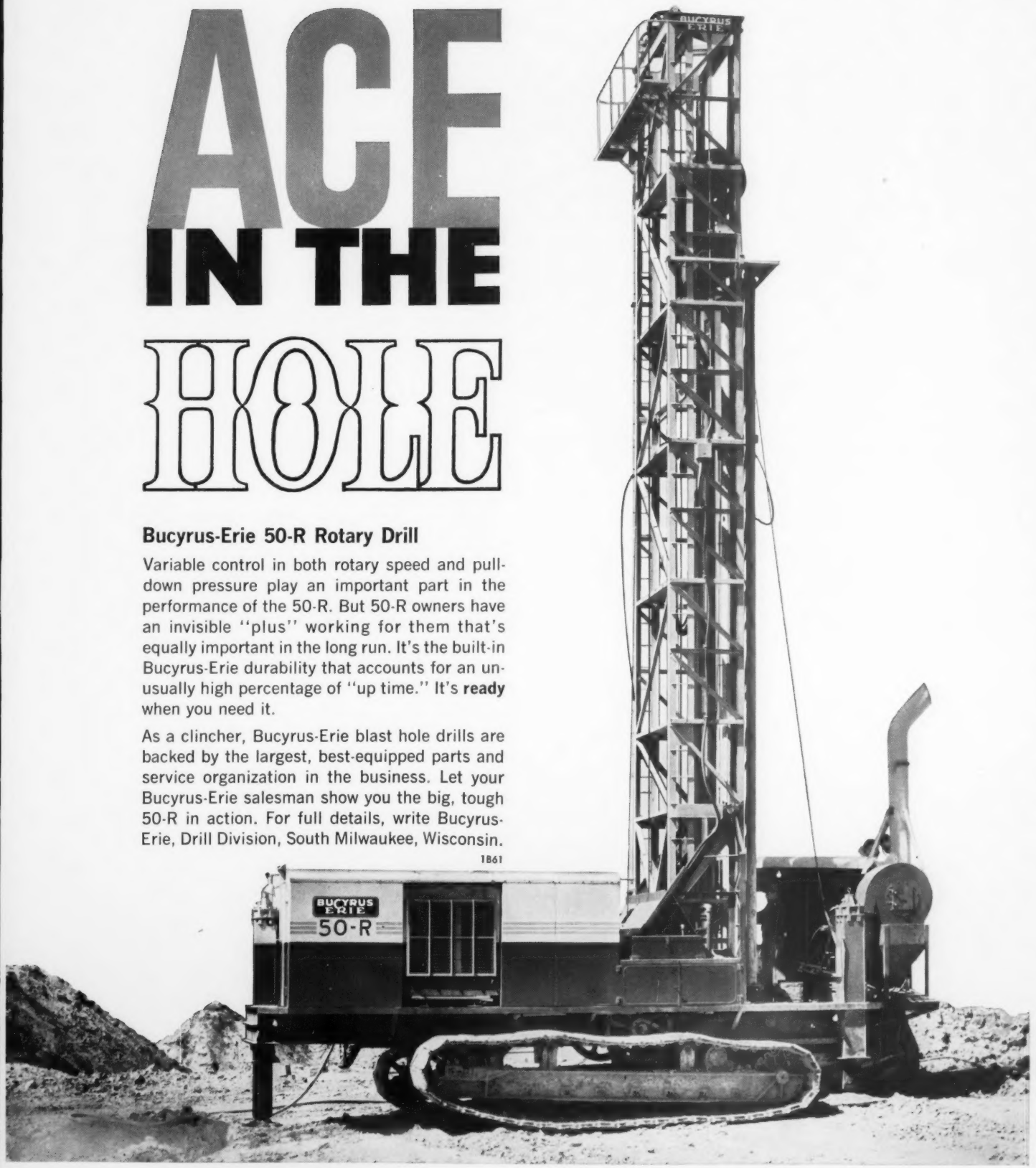

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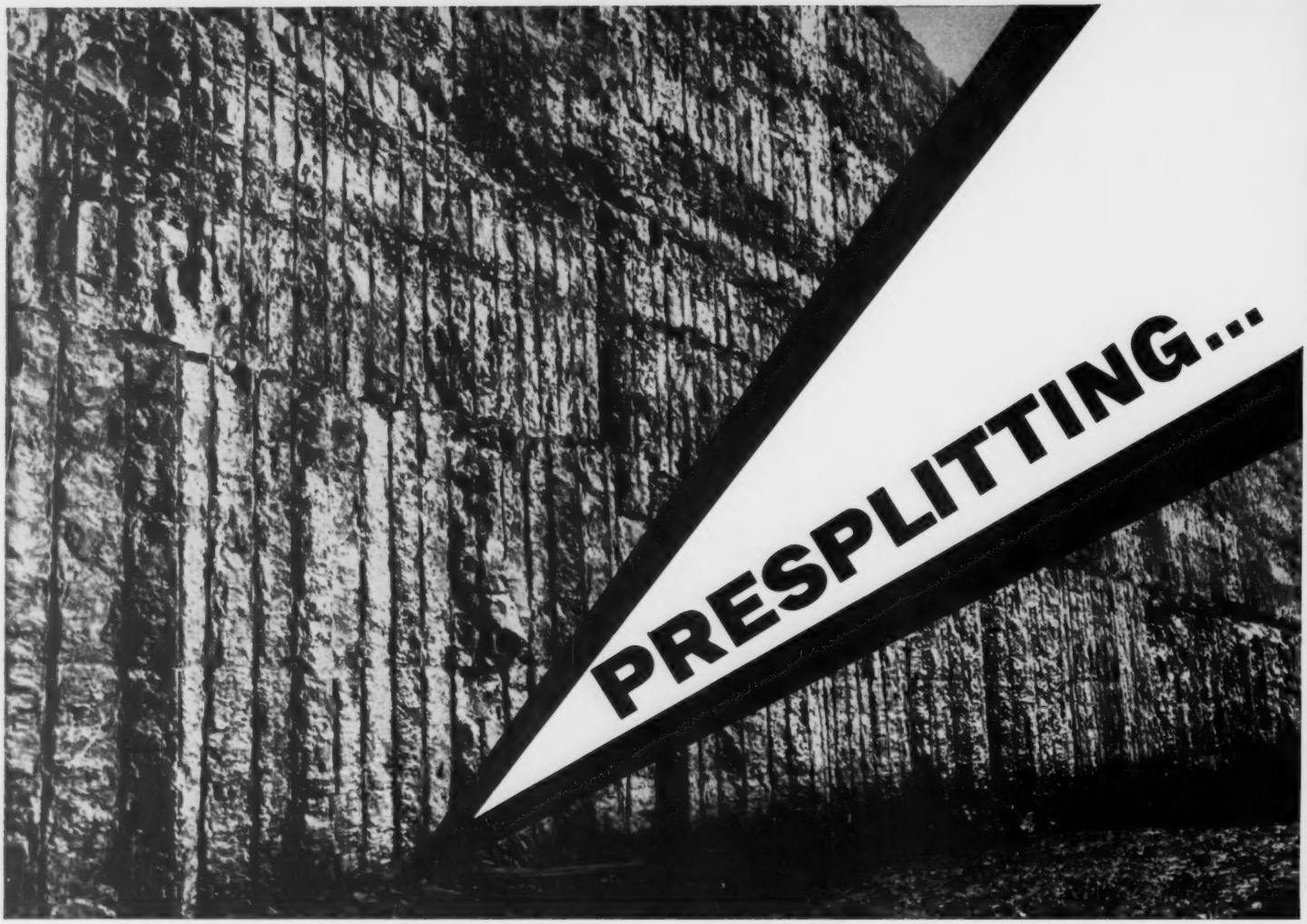

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